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(54) Refrigeration apparatus

(57) It is an object of the present invention to reduce occurrence of noise in an operation by inhibiting occurrence of flow sound of refrigerant. A refrigeration apparatus (1) is a refrigeration apparatus using supercritical refrigerant operating in a zone that high pressure of the supercritical refrigerant is equal to or greater than the critical pressure. The refrigeration apparatus (1) includes a compressor (21), a gas cooler (23, 31), an expansion mechanism (V2, V5), an evaporator (31, 23), discharge pressure detection means (P1, T2, T3) and a control section (5). The compressor is configured to compress the supercritical refrigerant. The gas cooler is configured to cool the supercritical refrigerant compressed by the compressor. The expansion mechanism is configured to decompress the supercritical refrigerant. The evaporator is configured to evaporate the supercritical refrigerant decompressed by the expansion mechanism. The discharge pressure detection means is capable of detecting discharge pressure of the compressor. The control section is configured to regulate the opening degree of the expansion mechanism for controlling the discharge pressure to be equal to or greater than the critical pressure when the refrigeration apparatus is activated and the discharge pressure is less than the critical pressure.

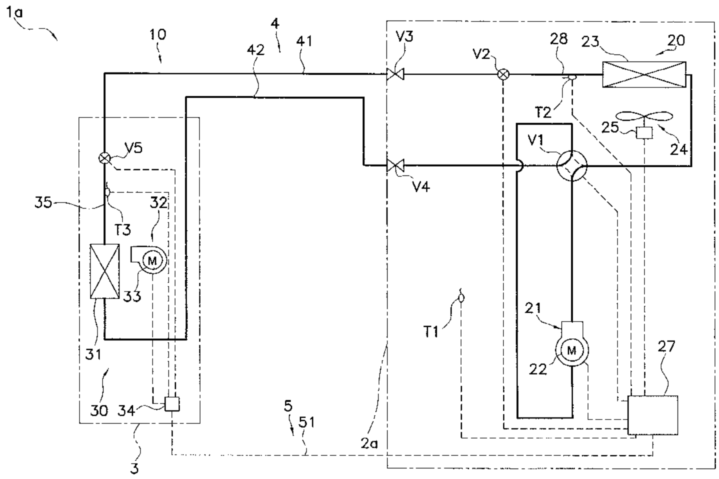

FIG. 7

EP 2 543 939 A2

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Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus using refrigerant operating in the supercritical zone.

BACKGROUND ART

[0002] A refrigeration apparatus, using supercritical refrigerant (e.g., CO_2 refrigerant) operating in the supercritical zone as refrigerant, has been conventionally produced (see Patent Document 1).

<Patent Document 1>

[0003] Japanese Laid-open Patent Application No. JP-A-2000-234814

DISCLOSURE OF THE INVENTION

<Technical Problem>

[0004] According to the aforementioned refrigeration apparatus, however, refrigerant in a gas-liquid two-phase state may flow into an expansion mechanism when high pressure of the refrigerant does not reach a fully pressurized level in the activation of the refrigeration apparatus or when temperature of the refrigerant does not reach the critical temperature because of low external temperature. In this case, flow sound of the refrigerant is easily generated in a vicinity of an inlet of the expansion mechanism. This will be a cause of noise to be produced when the refrigeration apparatus is operated.

[0005] It is an object of the present invention to reduce generation of noise in an operation of a refrigeration apparatus by inhibiting generation of flow sound of refrigerant.

<Solution to Problem>

[0006] A refrigeration apparatus according to a first aspect of the present invention is a refrigeration apparatus using supercritical refrigerant operating in a zone that high pressure of the supercritical refrigerant is equal to or greater than the critical pressure. The refrigeration apparatus includes a compressor, a gas cooler, an expansion mechanism, an evaporator, discharge pressure detection means and a control section. The compressor is configured to compress the supercritical refrigerant. The gas cooler is configured to cool the supercritical refrigerant compressed by the compressor. The expansion mechanism is configured to decompress the supercritical refrigerant. The evaporator is configured to evaporate the supercritical refrigerant decompressed by the expansion mechanism. The discharge pressure detection means is capable of detecting discharge pressure of the compressor. The control section is configured to regulate opening degree of the expansion mechanism for controlling the discharge pressure to be equal to or greater than the critical pressure when the refrigeration apparatus is activated and the discharge pressure is less than the critical pressure.

[0007] According to the first aspect of the present invention, the control section is configured to regulate the opening degree of the expansion mechanism for controlling the discharge pressure to be equal to or greater than the critical pressure when it determines that the discharge pressure is less than the critical pressure in the activation of the refrigeration apparatus.

[0008] Therefore, it is possible to change a state of the supercritical refrigerant in a vicinity of an inlet of the expansion mechanism from a gas-liquid two phase state to a supercritical state or a liquid-phase state by setting high pressure of the supercritical refrigerant in the refrigeration cycle to be equal to or greater than the critical pressure. Accordingly, it is possible to inhibit generation of flow sound due to a blowout of bubbles and the like.

[0009] A refrigeration apparatus according a second aspect of the present invention is the refrigeration apparatus according to the first aspect of the present invention, wherein the control section is configured to execute a first control for setting the opening degree of the expansion mechanism to be fully-closed or a slightly-opened degree when the discharge pressure is less than the critical pressure.

[0010] According to the second aspect of the present invention, the control section is configured to set the opening degree of the expansion mechanism to be fully-closed or a slightly opened degree when the discharge pressure is less than the critical pressure. Therefore, it is possible to easily set high pressure of the refrigerant in the refrigeration cycle to be equal to or greater than the critical pressure. Consequently, it is possible to inhibit generation of flow sound of the refrigerant in a vicinity of the inlet of the expansion mechanism.

[0011] A refrigeration apparatus according to a third aspect of the present invention is the refrigeration apparatus according to the second aspect of the present invention, wherein the control section is configured to execute a second control for setting the opening degree of the expansion mechanism to be large when the discharge pressure is equal to or greater than the critical pressure after the first control is executed.

[0012] When the refrigerant is pressurized to be equal to or greater than the critical pressure, the refrigerant enters a supercritical state or a liquid-phase state. In other words, the refrigerant is not in a gas-liquid two-phase state any more. Accordingly, it is possible to reduce generation of flow sound in a vicinity of the inlet of the expansion mechanism without further pressurizing the refrigerant.

[0013] According to the third aspect of the present invention, the control section is configured to execute the second control for opening the expansion mechanism when the discharge pressure is equal to or greater than the critical pressure after execution of the first control for easily increasing the high pressure of the refrigerant. Therefore, it is possible to optimally control the discharge pressure without unnecessarily increasing it. Consequently, it is possible to reduce energy consumption.

[0014] A refrigeration apparatus according to a fourth aspect of the present invention is the refrigeration apparatus according to any of the first to third aspects of the present invention, wherein the discharge pressure detection means is a pressure sensor provided at the discharge side of the compressor.

[0015] According to the fourth aspect of the present invention, the pressure sensor is configured to detect the discharge pressure and determination is made for whether or not the refrigerant is in a supercritical state. Therefore, it is possible to directly detect high pressure of the refrigerant in the refrigeration cycle based on the discharge pressure. Accordingly, it is possible to proceed to the second control from the first control while a period of time necessary for the first control is minimized. Also, it is possible to optimally control high pressure of the refrigerant without unnecessarily increasing it. Consequently, it is capable of reducing energy loss.

[0016] A refrigeration apparatus according to a fifth aspect of the present invention is the refrigeration apparatus according to any of the first to fourth aspects of the present invention, wherein the control section is configured to calculate inlet pressure of the expansion mechanism based on the discharge pressure and operational capacity of the compressor. Additionally, the control section is configured to regulate the opening degree of the expansion mechanism for controlling the discharge pressure to be equal to or greater than the critical pressure when the inlet pressure is less than the critical pressure.

[0017] According to the fifth aspect of the present invention, the inlet pressure of the expansion mechanism is calculated based on the discharge pressure and the compressor capacity. The discharge pressure and the inlet pressure of the expansion mechanism are different from each other because pressure-loss exists in the refrigerant pipe. Therefore, it is possible to more reliably control a state of the refrigerant in the vicinity of the inlet of the expansion mechanism (i.e., the cause of generation of noise) from a gas-liquid two-phase state to a supercritical state or a liquid-phase state.

[0018] A refrigeration apparatus according to a sixth aspect of the present invention is the refrigeration apparatus according to any of the first to third aspects of the present invention, wherein the pressure detection means is a temperature sensor capable of detecting temperature of the supercritical refrigerant in a range from an outlet of the gas cooler to an inlet of the expansion mechanism. Additionally, the control section is configured to determine that the inlet pressure is less than the critical pressure when the inlet temperature is less than the critical temperature, and is configured to regulate the opening degree of the expansion mechanism for controlling the inlet temperature to be equal to or greater than the critical temperature.

[0019] According to the sixth aspect of the present invention, the temperature sensor is configured to detect refrigerant temperature in a range from the outlet of the gas cooler to the inlet of the expansion mechanism, and determination is made for whether or not the refrigerant is in a supercritical state. Therefore, it is possible to determine that the refrigerant in a vicinity of the inlet of the expansion mechanism is not in a gas-liquid two-phase state, and it is also possible to reduce a blowout sound of bubbles and the like, which is a factor of flow sound. Furthermore, the pressure sensor in the fourth aspect of the present invention is allowed to be replaced by a temperature sensor, which is cheaper than the pressure sensor. Accordingly, it is possible to reduce its production cost.

[0020] A refrigeration apparatus according to a seventh aspect of the present invention is the refrigeration apparatus according to any of the first to sixth aspects of the present invention, wherein the refrigeration apparatus further includes a blower. The blower promotes cooling of the gas cooler. Additionally, the control section is configured to control the airflow volume of the blower to be small or zero when the refrigeration apparatus is activated and the discharge pressure is less than the critical pressure.

[0021] According to the seventh aspect of the present invention, the control section is configured to set the airflow volume of the blower, which is configured to blow air to the gas cooler for promoting cooling of the gas cooler, to be small or zero when the refrigeration apparatus is activated and the discharge pressure is less than the critical pressure. Therefore, it is possible to weaken a cooling effect in the gas cooler, and it is also possible to increase both temperature and pressure of the refrigerant in the gas cooler. Accordingly, it is possible to set a state of the refrigerant at the outlet of the gas cooler to be a supercritical state or a liquid-phase state. Consequently, it is possible to reduce generation of flow sound in a vicinity of the inlet of the expansion mechanism.

[0022] A refrigeration apparatus according to an eighth aspect of the present invention is the refrigeration apparatus according to any of the first to seventh aspects of the present invention, wherein the control section is configured to regulate the opening degree of the expansion mechanism for controlling the discharge pressure to be equal to or greater than the critical pressure when a normal operation is executed.

[0023] According to the eighth aspect of the present invention, the control section is configured to control the discharge pressure to be equal to or greater than the critical pressure not only in the activation of the refrigeration apparatus but also in the normal operation. Therefore, it is always possible to set a state of the refrigerant in a vicinity of the inlet of the expansion mechanism to be a supercritical state or a liquid-phase state. Consequently, it is possible to reduce generation of flow sound at the inlet of the expansion mechanism.

[0024] A refrigeration apparatus according to a ninth aspect of the present invention is the refrigeration apparatus according to any of the first to seventh aspects of the present invention, wherein the control section is configured to regulate the opening degree of the expansion mechanism for controlling the discharge pressure to be equal to or greater than the critical pressure even when a normal operation is executed at a low external temperature.

[0025] When the normal operation is executed at the low external temperature, refrigerant in a vicinity of the inlet of the expansion mechanism may be in a gas-liquid two-phase state. According to the ninth aspect of the present invention, the control section is configured to regulate the opening degree of the expansion mechanism for controlling high pressure of the supercritical refrigerant to be equal to or greater than the critical pressure even at the low external temperature. Therefore, it is possible to set a state of the refrigerant in a vicinity of the inlet of the expansion mechanism to be a supercritical state or a liquid-phase state.

[0026] A refrigeration apparatus according to a tenth aspect of the present invention is the refrigeration apparatus according to the ninth aspect of the present invention, wherein the low external temperature is defined as the external temperature equal to or less than 20 degrees Celsius.

[0027] According to the tenth aspect of the present invention, the discharge pressure is controlled to be equal to or greater than the critical pressure under a condition that the supercritical refrigerant easily enters a gas-liquid two-phase state (e.g., a condition that the external temperature is equal to or less than 20 degrees Celsius). Therefore, it is possible to change a state of the supercritical refrigerant in a vicinity of the inlet of the expansion mechanism from a gas-liquid two-phase state to a supercritical state or a liquid-phase state even when the external temperature is equal to or less than 20 degrees Celsius.

[0028] A refrigeration apparatus according to an eleventh aspect of the present invention is a refrigeration apparatus using supercritical refrigerant operating in a zone that high pressure of the supercritical refrigerant is equal to or greater than the critical pressure. The refrigeration apparatus includes a compressor, a gas cooler, an expansion mechanism, an evaporator, temperature detection means and a control section. The compressor is configured to compress the supercritical refrigerant. The gas cooler is configured to cool the supercritical refrigerant compressed by the compressor. The expansion mechanism is configured to decompress the supercritical refrigerant. The evaporator is configured to evaporate the supercritical refrigerant decompressed by the expansion mechanism. The temperature detection means is capable of detecting inlet temperature of the expansion mechanism. The control section is configured to regulate the opening degree of the expansion mechanism for controlling the inlet temperature to be equal to or greater than critical temperature when the refrigeration apparatus is activated and the inlet temperature is less than the critical temperature.

[0029] According to the eleventh aspect of the present invention, the control section is configured to regulate the opening degree of the expansion mechanism for controlling the inlet temperature of the expansion mechanism to be equal to or greater than the critical temperature when it determines that the inlet temperature of the expansion mechanism is less than the critical temperature. Therefore, it is possible to set a state of the supercritical refrigerant at the inlet of the expansion mechanism to be a supercritical state, not a gas-liquid two-phase state, by setting temperature of the supercritical refrigerant at the inlet of the expansion mechanism in the refrigeration cycle to be equal to or greater than the critical temperature. Consequently, it is possible to inhibit generation of flow sound in a vicinity of the inlet of the expansion mechanism.

[0030] A refrigeration apparatus according to a twelfth aspect of the present invention is the refrigeration apparatus according to any of the first to eleventh aspects of the present invention, wherein the supercritical refrigerant is carbon dioxide (CO_2) refrigerant.

[0031] According to the twelfth aspect of the present invention, the CO_2 refrigerant is used as refrigerant. Ozone depletion potential (ODP) of the CO_2 refrigerant equals to zero. Therefore, the CO_2 refrigerant does not destroy the ozone layer above the earth. Furthermore, global warming potential (GWP) of the CO_2 refrigerant equals to 1. This is much lower than GWP of fluorocarbon refrigerant of about hundreds to ten thousand. Accordingly, the refrigerant apparatus is capable of inhibiting worsening of global environment with use of the CO_2 refrigerant with less environmental burden.

<Advantageous Effects of Invention>

[0032] According to the refrigeration apparatus of the first aspect of the present invention, it is possible to change a state of the supercritical refrigerant from a gas-liquid two-phase state to a supercritical state or a liquid-phase state by setting high pressure of the supercritical refrigerant in the refrigeration cycle to be equal to or greater than the critical pressure. Therefore, it is possible to inhibit generation of flow sound due to a blowout of bubbles and the like.

[0033] According to the refrigeration apparatus of the second aspect of the present invention, it is possible to easily set high pressure of the supercritical refrigerant in the refrigeration cycle to be equal to or greater than the critical pressure. Therefore, it is possible to inhibit generation of flow sound due to a blowout of bubbles and the like.

[0034] According to the refrigeration apparatus of the third aspect of the present invention, it is possible to optimally control the discharge pressure without unnecessarily increasing it. Consequently, it is possible to reduce energy consumption.

[0035] According to the refrigeration apparatus of the fourth aspect of the present invention, it is possible to directly detect high pressure of the supercritical refrigerant in the refrigeration cycle based on the discharge pressure. Therefore, it is possible to proceed to the second control from the first control while a period of time necessary for the first control is minimized. Also, it is possible to optimally control high pressure of the supercritical refrigerant without unnecessarily increasing it. Consequently, it is possible to reduce energy loss.

[0036] According to the refrigeration apparatus of the fifth aspect of the present invention, it is possible to more reliably control a state of the refrigerant in a vicinity of the inlet of the expansion mechanism (i.e., the cause of generation of noise) from a gas-liquid two-phase state to a supercritical state or a liquid-phase state.

[0037] According to the refrigeration apparatus of the sixth aspect of the present invention, it is possible to determine that the refrigerant in a vicinity of the inlet of the expansion mechanism is not in a gas-liquid two-phase state, and it is also possible to reduce a blowout sound of bubbles and the like, which is a factor of flow sound. Furthermore, the pressure sensor in the fourth aspect of the present invention is allowed to be replaced by a temperature senor, which is cheaper than the pressure sensor. Accordingly, it is possible to reduce its production cost.

[0038] According to the refrigeration apparatus of the seventh aspect of the present invention, it is possible to weaken a cooling effect in the gas cooler, and it is also possible to increase both temperature and pressure of refrigerant in the gas cooler. Therefore, it is possible to set a state of the refrigerant at the outlet of the gas cooler to be a supercritical state or a liquid-phase state. Consequently, it is possible to reduce generation of flow sound in a vicinity of the inlet of the expansion mechanism.

[0039] According to the refrigeration apparatus of the eighth aspect of the present invention, it is possible to always set a state of the refrigerant in a vicinity of the inlet of the expansion mechanism to be a supercritical state or a liquid-phase state. Therefore, it is possible to reduce generation of flow sound at the inlet of the expansion mechanism.

[0040] According to the refrigeration apparatus of the ninth aspect of the present invention, it is possible to set a state of the refrigerant in a vicinity of the inlet of the expansion mechanism to be a supercritical state or a liquid-phase state even at the low external temperature.

[0041] According to the refrigeration apparatus of the tenth aspect of the present invention, it is possible to change a state of the supercritical refrigerant from a gas-liquid two-phase state to a supercritical state or a liquid-phase state even when the external temperature is equal to or less than 20 degrees Celsius.

[0042] According to the refrigeration apparatus of the eleventh aspect of the present invention, it is possible to set a state of the supercritical refrigerant at the inlet of the expansion mechanism to be a supercritical state, not a gas-liquid two-phase state, by setting temperature of the supercritical refrigerant at the inlet of the expansion mechanism in the refrigeration cycle to be equal to or greater than the critical temperature. Therefore, it is possible to inhibit generation of flow sound due to a blowout of bubbles and the like.

[0043] According to the refrigeration apparatus of the twelfth aspect of the present invention, it is possible to inhibit worsening of global environment with use of the CO_2 refrigerant with less environmental burden.

BRIEF DESCRIPTION OF THE DRAWING

[0044]

Fig. 1 is a refrigeration circuit diagram of an air conditioning apparatus according to an embodiment of the present invention.

Fig. 2 is a control block diagram of the air conditioning apparatus.

Fig. 3 is a flow chart of an activation mode.

Fig. 4 is a flow chart of a normal mode.

Fig. 5 is a time-flow chart for illustrating timing of switching between a throttle control and a normal control.

Fig. 6 is a P-H chart (Mollier chart) of a supercritical refrigeration cycle.

Fig. 7 is a refrigeration circuit diagram of an air conditioning apparatus according to Modification (2).

EXPLANATION OF THE REFERENCE NUMERALS

[0045]

1, 1a	air conditioning apparatus (refrigeration apparatus)
5	control section
21	compressor
23	outdoor heat exchanger (gas cooler, evaporator)
24	outdoor fan (blower)
31	indoor heat exchanger (gas cooler, evaporator)
32	indoor fan (blower)
P1	discharge pressure sensor (pressure sensor)
T2	first liquid pipe temperature sensor (temperature sensor)
T3	second liquid pipe temperature sensor (temperature sensor)
V2	outdoor expansion valve (expansion mechanism)
V5	indoor expansion valve (expansion mechanism)

BEST MODE FOR CARRYING OUT THE INVENTION

[0046] An air conditioning apparatus according to an embodiment of the present invention will be hereinafter explained with reference to the accompanying drawings.

<Structure of Air Conditioning Apparatus>

[0047] Fig. 1 is a schematic configuration diagram of an air conditioning apparatus 1 according to an embodiment of the present invention. The air conditioning apparatus 1 is an apparatus used for cooling and heating the indoor space of a building and the like. In the present invention, carbon dioxide (CO_2) refrigerant, which is supercritical refrigerant, is used. The air conditioning apparatus 1 mainly includes an outdoor unit 2, an indoor unit 3 and a refrigerant communication pipe 4. The outdoor unit 2 functions as a heat source unit. The indoor unit 3 is connected to the outdoor unit 2, and functions as a utilization unit. The refrigerant communication pipe 4 connects the indoor unit 3 and the outdoor unit 2. The refrigerant communication pipe 4 is composed of a liquid refrigerant communication pipe 41 and a gas refrigerant communication pipe 42. In other words, a refrigerant circuit 10 of the air conditioning apparatus 1 according to the present embodiment is formed by the interconnection among the outdoor unit 2, the indoor unit 3 and the refrigerant communication pipe 4.

(1) Outdoor Unit

[0048] The outdoor unit 2 is disposed outside a building and the like. The outdoor unit 2 is connected to the indoor unit 3 through the refrigerant communication pipe 4. The outdoor unit 2 forms a part of the refrigerant circuit 10.

[0049] Next, structure of the outdoor unit 2 will be explained. The outdoor unit 2 mainly includes an outdoor side refrigerant circuit 20. The outdoor side refrigerant circuit 20 forms a part of the refrigerant circuit 10. The outdoor side refrigerant circuit 20 mainly includes a compressor 21, a four-way switch valve V1, an outdoor heat exchanger 23 functioning as a heat source side heat exchanger, an outdoor expansion valve V2 functioning as an expansion mechanism, a liquid side stop valve V3 and a gas side stop valve V4.

[0050] The compressor 21 is a compressor capable of changing its operation capacity. In the present embodiment, the compressor 21 is a positive-displacement compressor to be driven by a motor 22. Here, rotation speed of the motor 22 is controlled by an inverter. Furthermore, only single compressor 21 is provided in the present embodiment. However, the number of the compressor 21 is not limited to this. For example, two or more compressors may be parallel-connected depending on the number of indoor units and the like to be connected to the outdoor unit 2.

[0051] The four-way switch valve V1 is a valve provided for causing the outdoor heat exchanger 23 to function as a gas cooler and an evaporator. The four-way switch valve V1 is connected to the outdoor heat exchanger 23, a suction side of the compressor 21, a discharge side of the compressor 21 and the gas refrigerant communication pipe 42. When the outdoor heat exchanger 23 is caused to function as a gas cooler, the four-way switch valve V1 is configured to connect the discharge side of the compressor 21 and the outdoor heat exchanger 23, and is also configured to connect the suction side of the compressor 21 and the gas refrigerant communication pipe 42 (see a solid-line condition in Fig. 1). On the other hand, when the outdoor heat exchanger 23 is caused to function as an evaporator, the four-way switch valve V1 is configured to connect the outdoor heat exchanger 23 and the suction side of the compressor 21, and is also configured to connect the discharge side of the compressor 21 and the gas refrigerant communication pipe 42 (see a dashed-line condition in Fig. 1).

[0052] The outdoor heat exchanger 23 is a heat exchanger allowed to function as a gas cooler or an evaporator. In the present embodiment, the outdoor heat exchanger 23 is a cross-fin typed fin-and-tube heat exchanger for conducting heat exchange between the refrigerant and air functioning as a heat source. One end of the outdoor heat exchanger 23 is connected to the four-way switch valve V1 while the other end thereof is connected to the outdoor expansion valve V2.

[0053] The outdoor expansion valve V2 is an electric expansion valve for regulating the pressure, the flow rate and the like of refrigerant flowing through the outdoor side refrigerant circuit 20. The outdoor expansion valve V2 is connected between the outdoor heat exchanger 23 and the liquid side stop valve V3 for this purpose.

[0054] Furthermore, the outdoor unit 2 includes an outdoor fan 24. The outdoor fan 24 functions as a ventilation fan for sucking outdoor air into the outdoor unit 2 and then discharging the air to the outside after the outdoor heat exchanger 23 conducts heat exchange between the sucked air and the refrigerant. The outdoor fan 24 is a fan capable of changing the flow rate of air to be supplied to the outdoor heat exchanger 23. In the present embodiment, the outdoor fan 24 is a propeller fan to be driven by a motor 25, for instance. The motor 25 is composed of a DC fan motor.

[0055] Additionally, the outdoor unit 2 is provided with a variety of sensors. Specifically, the outdoor unit 2 is provided with a discharge pressure sensor P1 for detecting discharge pressure Pd of the compressor 21. The outdoor unit 2 is also provided with an external temperature sensor T1 for detecting temperature of the outdoor air (i.e., external temperature) flowing into the outdoor unit 2. The external temperature sensor T1 is disposed at the outdoor-air suction side of the outdoor unit 2. In the present embodiment, the external temperature sensor T1 is composed of a thermistor.

[0056] Moreover, the outdoor unit 2 includes an outdoor side control unit 27. The outdoor side control unit 27 is configured to control operations of respective elements forming the outdoor unit 2. The outdoor side control unit 27 includes a microcomputer, a memory, an inverter circuit and the like. The microcomputer is provided for controlling the outdoor unit 2. The inverter circuit is configured to control the motor 22 and the like. The outdoor side control unit 27 is capable of transmitting/receiving a control signal and the like to/from an after-mentioned indoor side control unit 34 of the indoor unit 3 through a transmission line 51. In other words, the outdoor side control unit 27, the indoor side control unit 34 and the transmission line 51 connecting each of the control units 27 and 34 form a control section 5 for controlling the entire operation of the air conditioning apparatus 1.

[0057] The elements of the control section 5 are connected for receiving detection signals from various sensors P1 and T1 and for controlling the various devices 21, 24 and 32 and valves V1, V2 and V5, respectively, based on the detection signals and the like. Now, Fig.2 is a control block diagram of the air conditioning apparatus 1.

(2) Indoor Unit

[0058] The indoor unit 3 is installed by being embedded in or hanged down from the ceiling of the indoor space of a building and the like, or hanged down on the wall thereof, for instance. The indoor unit 3 is connected to the outdoor unit 2 through the refrigerant communication pipe 4. The indoor unit 3 forms a part of the refrigerant circuit 10.

[0059] Next, a configuration of the indoor unit 3 will be explained. The indoor unit 3 mainly includes an indoor side refrigerant circuit 30. The indoor side refrigerant circuit 30 forms a part of the refrigerant circuit 10. The indoor side refrigerant circuit 30 mainly includes an indoor heat exchanger 31 and an indoor expansion valve V5. The indoor heat exchanger 31 functions as a utilization side heat exchanger. The indoor expansion valve V5 functions as an expansion mechanism.

[0060] The indoor heat exchanger 31 is a cross-fin typed fin-and-tube heat exchanger formed by a heat transmission tube and a plurality of fins. The indoor heat exchanger 31 is configured to function as an evaporator of the refrigerant for cooling the indoor air in the cooling operation. On the other hand, the indoor heat exchanger 31 is configured to function as a gas cooler of the refrigerant for heating the indoor air in the heating operation.

[0061] The indoor expansion valve V5 is an electric expansion valve for regulating the pressure, the flow rate and the like of the refrigerant flowing through the indoor side refrigerant circuit 30. The indoor expansion valve V5 is connected to the liquid side of the indoor heat exchanger 31. In this regard, the indoor expansion valve V5 is similar to the aforementioned outdoor expansion valve V2.

[0062] Furthermore, the indoor unit 3 includes an indoor fan 32. The indoor fan 32 functions as a ventilation fan for sucking the indoor air into the indoor unit 3 and subsequently supplying the sucked air to the indoor space as the supply air after the indoor heat exchanger 31 conducts heat exchange between the refrigerant and the sucked air. The indoor fan 32 is a fan capable of changing the flow rate of air to be supplied to the indoor heat exchanger 31. In the present embodiment, the indoor fan 32 is a centrifugal fan, a multi-blade fan and the like to be driven by a motor 33. Here, the motor 33 is composed of a DC fan motor.

[0063] Moreover, the indoor unit 3 is provided with the indoor side control unit 34 for controlling operations of each of the elements forming the indoor unit 3. The indoor side control unit 34 includes a microcomputer, a memory and the like provided for controlling the indoor unit 3. The indoor side control unit 34 is capable of transmitting/receiving a control signal and the like to/from a remote controller (not illustrated in the figure) for individually operating a corresponding indoor unit 3. Additionally, the indoor side control unit 34 is capable of transmitting/receiving a control signal and the like to/from the outdoor unit 2 through the transmission line 51, for instance.

(3) Refrigerant Communication Pipe

[0064] When the air conditioning apparatus 1 is installed in an installation place of a building and the like, the refrigerant communication pipe 4 is attached to the air conditioning apparatus 1 in the installation site. Any suitable refrigerant communication pipes 4 of a variety of lengths and diameters may be used depending on an installation condition (e.g., an installation site and a combination of the outdoor unit 2 and the indoor unit 3).

<Operations of Air Conditioning Apparatus>

[0065] Next, operations of the air conditioning apparatus 1 according to the present embodiment will be explained.

[0066] The air conditioning apparatus 1 according to the present embodiment is configured to be operated in two operation modes. One of the operation modes is an activation mode to be executed in the activation of the air conditioning apparatus 1 until the refrigeration cycle becomes stable. The other of the operation modes is a normal mode to be executed after the refrigeration cycle becomes stable. Furthermore, the normal mode is classified into two operation types. One of the operation types is a cooling operation for causing the indoor unit 3 to cool the indoor space depending on cooling load of the indoor unit 3. The other of the operation types is a heating operation for causing the indoor unit 3 to heat the indoor space depending on heating load of the indoor unit 3.

[0067] Operations of the air conditioning apparatus 1 in each of the operation modes will be hereinafter explained.

(1) Activation Mode

[0068] Fig. 3 is a flowchart for illustrating a series of control processing to be executed in the activation mode. When the air conditioning apparatus 1 is operated for executing either a cooling operation or a heating operation (i.e., when the compressor 21 is activated), the activation mode is accordingly activated. The activation mode will be hereinafter explained with reference to Fig. 3.

[0069] First, in Step S1, it is determined if the discharge pressure Pd, detected by the discharge pressure sensor P1, is less than the critical pressure Pk of the CO_2 refrigerant. When the discharge pressure Pd is less than the critical pressure Pk, the control processing proceeds to Step S2. On the other hand, when the discharge pressure Pd is equal to or greater than the critical pressure Pk, the control processing proceeds to Step S3. In Step S2, a throttle control is executed for reducing a throttle opening degree θ1 of the outdoor expansion valve V2 in a cooling operation, whereas a throttle control is executed for reducing a throttle opening degree θ2 of the indoor expansion valve V5 in a heating operation. In the "throttle control" herein referred, the throttle opening degrees θ1 and θ2 are controlled to be an opening degree α (see Fig. 5 to be described). When the throttle opening degrees θ1 and θ2 are set to be the opening degree α, flow sound of the gas-liquid two-phase state CO_2 refrigerant is not generated when the CO_2 refrigerant passes through the outdoor expansion valve V2 or the indoor expansion valve V5. When the discharge pressure Pd is less than the critical pressure Pk, the CO_2 refrigerant could be in a gas-liquid two-phase state, not in a supercritical state, at a higher possibility. When the CO_2 refrigerant is in a gas-liquid two-phase state, flow sound of the CO_2 refrigerant is easily generated in a vicinity of the outdoor expansion valve V2 or the indoor expansion valve V5. Therefore, high pressure of the CO_2 refrigerant is promoted to be equal to or greater than the critical pressure Pk in the refrigeration cycle in a shorter period of time by setting the throttle opening degree θ1 of the outdoor expansion valve V2 or the throttle opening degree θ2 of the indoor expansion valve V5 to be the opening degree α. When Step S2 is completed, the control processing returns to Step S1. In Step S3, the activation mode proceeds to the normal mode.

(2) Normal Mode

[0070] Fig. 4 is a flowchart for illustrating a series of control processing to be executed in the normal mode. The normal mode is started after the aforementioned activation mode is completed.

[0071] First, in Step S11, it is determined if the discharge pressure Pd, detected by the discharge pressure sensor P1, is less than the critical pressure Pk of the CO_2 refrigerant. When the discharge pressure Pd is less than the critical pressure Pk, the control processing proceeds to Step S 12. On the other hand, when the discharge pressure Pd is equal to or greater than the critical pressure Pk, the control processing proceeds to Step S15. In Step S12, throttle control is executed for reducing the throttle opening degree θ1 of the outdoor expansion valve V2 in a cooling operation, whereas throttle control is executed for reducing the throttle opening degree θ2 of the indoor expansion valve V5 in a heating operation. When Step S12 is completed, the control processing proceeds to Step S 13. In Step S 13, it is determined if the outdoor fan 24 is being driven in the cooling operation, whereas it is determined if the indoor fan 32 is being driven in the heating operation. When the outdoor fan 24 or the indoor fan 32 is being driven, the control processing proceeds to Step S14. On the other hand, when the outdoor fan 24 or the indoor fan 32 is not being driven, the control processing returns to Step S11. In Step S14, the outdoor fan 24 or the indoor fan 32 is stopped. When Step S 14 is completed, the control processing returns to Step S11. In Step S 15 to be executed when the external temperature exceeds 20 degrees Celsius in Step S11, it is determined if throttle control is being executed with respect to the outdoor expansion valve V2 or the indoor expansion valve V5. When throttle control is being executed with respect to the outdoor expansion valve V2 or the indoor expansion valve V5, the control processing proceeds to Step S 16. On the other hand, when normal control is being executed with respect to the outdoor expansion valve V2 or the indoor expansion valve V5, the control processing returns to Step S11. In Step S16, normal control is executed with respect to the outdoor expansion valve V2 or the indoor expansion valve V5. Note the term "normal control" means control processing to be executed in the after-mentioned cooling operation or the after-mentioned heating operation. When Step S16 is completed, the control processing proceeds to Step S 17. In Step S17, it is determined if the outdoor fan 24 or the indoor fan 32 is being stopped. When the outdoor fan 24 or the indoor fan 32 is being stopped, the control processing proceeds to Step S18. On the other hand, when the outdoor fan 24 or the indoor fan 32 is being driven, the control process returns to Step S11. In Step S 18, the outdoor fan 24 or the indoor fan 32 is activated, and normal control is executed with respect to the outdoor fan 24 or the indoor fan 32. When Step S18 is completed, the control processing returns to Step S11.

(3) Throttle Control and Normal Control

[0072] As illustrated in the aforementioned flowchart of the normal mode, the control section 5 is configured to switch controls of the outdoor expansion valve V2 or the indoor expansion valve V5 between the throttle control and the normal control. Fig. 5 is a time-flow chart for illustrating timing of switching the throttle control and the normal control back and forth. In Fig. 5, the horizontal axis represents time t while the vertical axis represents the discharge pressure Pd and the throttle opening degree θ1 of the outdoor expansion valve V2 or the throttle opening degree θ2 of the indoor expansion valve V5. When the activation time is assumed to be time t1 and the discharge pressure Pd in the activation is assumed to be initial discharge pressure P0, throttle control is started at time t1 and the throttle opening degree $\theta 1$ of the outdoor expansion valve V2 or the throttle opening degree $\theta 2$ of the indoor expansion valve V5 is set to be the opening degree a. Subsequently, when time t2 is elapsed and the discharge pressure Pd is changed from the initial discharge pressure P0 to critical pressure Pk, the throttle control is switched to the normal control. Accordingly, the throttle opening degree $\theta 1$ of the outdoor expansion valve V2 or the throttle opening degree $\theta 2$ of the indoor expansion valve V5 is set to be opening degree β. Furthermore, when the discharge pressure Pd is equal to or less than the critical pressure Pk (time t3), for instance, under a condition that the external temperature is equal to or less than 20 degrees Celsius, the normal control is again switched to the throttle control. At this time, the throttle opening degree 81 of the outdoor expansion valve V2 or the throttle opening degree $\theta 2$ of the indoor expansion valve V5 is set to be the opening degree α.

[0073] Next, a cooling operation and a heating operation, executed in the normal control, will be explained.

(4) Cooling Operation

[0074] First, a cooling operation will be hereinafter explained with reference to Fig. 1. In the cooling operation, the four-way switch valve V1 in the outdoor side refrigerant circuit 20 of the outdoor unit 2 is switched to the solid-line condition in Fig. 1. Accordingly, the outdoor heat exchanger 23 is configured to function as a gas cooler whereas the indoor heat exchanger 31 is configured to function as an evaporator.

[0075] When the compressor 21, the outdoor fan 24 and the indoor fan 32 are activated under the condition of the refrigerant circuit 10, the gas refrigerant of low pressure P1 is sucked into the compressor 21 and is therein compressed. The gas refrigerant changes into the gas refrigerant of high pressure Ph. The gas refrigerant, compressed to the high pressure Ph, flows into the outdoor heat exchanger 23. At this time, the outdoor heat exchanger 23 functions as a gas cooler and cools the refrigerant by releasing heat of the refrigerant into the outdoor air to be supplied by the outdoor fan 24. Subsequently, the outdoor expansion valve V2 decompresses the refrigerant from the high pressure Ph to the low pressure P1. The refrigerant, decompressed to the low pressure P1, changes into gas-liquid two-phase refrigerant. The gas-liquid two-phase refrigerant is transported to the indoor unit 3 via the liquid side stop valve V3 and the liquid refrigerant communication pipe 41.

[0076] Next, the indoor expansion valve V5 controls the flow rate of the gas-liquid two-phase refrigerant of the low pressure P1 transported to the indoor unit 3. The indoor heat exchanger 31 then conducts heat change between the refrigerant and the indoor air. The refrigerant accordingly evaporates and changes into gas refrigerant of the low pressure P1. The gas refrigerant of the low pressure P1 is transported to the outdoor unit 2 via the gas refrigerant communication pipe 42. The gas refrigerant is again sucked into the compressor 21 via the gas side stop valve V4.

(5) Heating Operation

[0077] In the heating operation, the four-way switch valve V1 in the outdoor side refrigerant circuit 20 of the outdoor unit 2 is switched to the dashed-line condition in Fig. 1. Accordingly, the outdoor heat exchanger 23 is configured to function as an evaporator whereas the indoor heat exchanger 31 is configured to function as a gas cooler.

[0078] When the compressor 21, the outdoor fan 24 and the indoor fan 32 are activated under the condition of the refrigerant circuit 10, gas refrigerant of the low pressure P1 is sucked into the compressor 21 and is therein compressed. Accordingly, the refrigerant changes into gas refrigerant of the high pressure Ph. The refrigerant is then transported to the gas refrigerant communication pipe 42 via the four-way switch valve V1 and the gas side stop valve V4.

[0079] The gas refrigerant of the high pressure Ph, transported to the gas refrigerant communication pipe 42, is further transported to the indoor unit 3. The gas refrigerant of the high pressure Ph, transported to the indoor unit 3, is further transported to the indoor heat exchanger 31. The indoor heat exchanger 31 conducts heat exchange between the refrigerant and the indoor air. The refrigerant is accordingly cooled, and changes into liquid refrigerant of the high pressure Ph. Subsequently, when the refrigerant passes through the indoor expansion valve V5, it is decompressed to the low pressure P1 in accordance with the throttle opening degree $\theta 2$ of the indoor expansion valve V5. The refrigerant accordingly changes into gas-liquid two-phase refrigerant.

[0080] Next, the gas-liquid two-phase refrigerant is transported to the outdoor unit 2 via the liquid refrigerant communication pipe 41. The refrigerant flows into the outdoor heat exchanger 23 via the liquid side stop valve V3 and the outdoor expansion valve V2.

[0081] The outdoor heat exchanger 23 conducts heat exchange between the refrigerant and the external air. The refrigerant accordingly evaporates and changes into gas refrigerant of the low pressure P1. At this time, the outdoor expansion valve V2 is fully opened. The gas refrigerant of the low pressure P1 is again sucked into the compressor 21 via the four-way switch valve V1.

<Supercritical Refrigeration Cycle>

[0082] Next, a refrigeration cycle in the air conditioning apparatus 1 will be explained. Fig. 6 illustrates a refrigeration cycle under the supercritical condition with a P-H chart (Mollier chart). In Fig. 6, points A, B, C and D indicate states of refrigerant at the corresponding points in Fig. 1 of the cooling operation. Furthermore, in Fig. 6, points (A), (F), (E) and (D) indicate states of refrigerant at the corresponding points in Fig. 1 of the heating operation.

[0083] In the refrigerant circuit 10, the compressor 21 compresses the refrigerant and the compressed refrigerant changes into high-temperature refrigerant of the high pressure Ph (A→B). At this time, the gas refrigerant, CO_2, enters a supercritical state. Note the term "supercritical state" herein referred means a state of material at temperature and pressure equal to or greater than the critical point K. In the supercritical state, material has both gas diffusivity and liquid solubility. In Fig. 6, the supercritical state is a state of refrigerant shown in the area positioned rightward of a critical temperature isothermal curve Tk at the critical pressure Pk or greater. When the refrigerant (material) enters a supercritical state, there is no distinction between gas and liquid phases. Note the term "gas phase" herein referred is a state of refrigerant shown in the area positioned rightward of a saturated vapor curve Sv at the critical pressure Pk or less. Additionally, the term "liquid phase" is a state of refrigerant shown in the area positioned leftward of a saturated liquid curve S1 and leftward of the critical temperature isothermal curve Tk. The outdoor heat exchanger 23, functioning as a gas cooler, releases heat of the supercritical-state refrigerant of high temperature and the high pressure Ph produced by the compression of the compressor 21. Accordingly, the refrigerant changes into low-temperature refrigerant of the high pressure Ph (B→C). At this time, the refrigerant is in a supercritical state, and therefore operates with sensible heat changes (temperature changes) in the interior of the outdoor heat exchanger 23. Subsequently, the refrigerant, heat of which has been released by the outdoor heat exchanger 23 is expanded by the outdoor expansion valve V2 being opened. Thus the refrigerant is decompressed from the high pressure Ph to the low pressure P1 (C→D). The refrigerant, decompressed by the outdoor expansion valve V2, absorbs heat and evaporates in the indoor heat exchanger 31 functioning as an evaporator, and returns to the compressor 21 (D→A).

<Characteristics>

(1)

[0084] According to the present embodiment, when the control section 5 determines that the discharge pressure Pd in the refrigeration cycle is less than the critical pressure Pk in the activation mode, it regulates the throttle opening degree θ1 of the outdoor expansion valve V2 or the throttle opening degree θ2 of the indoor expansion valve V5 to be very small opening degree, that is, the opening degree α, for easily controlling the discharge pressure Pd to be equal to or greater than the critical pressure Pk. Furthermore, similar control is executed in the normal mode.

[0085] Therefore, it is possible to change a state of the CO_2 refrigerant from a gas-liquid two-phase state to a supercritical state or a liquid phase state. As a result, it is possible to inhibit generation of flow sound of the refrigerant in a vicinity of an inlet of the outdoor expansion valve V2 and an inlet of the indoor expansion valve V5.

(2)

[0086] According to the present embodiment, when the discharge pressure Pd is equal to or greater than the critical pressure Pk after the throttle control is executed, the control section 5 is configured to execute normal control of the outdoor expansion valve V2 or the indoor expansion valve V5. When the CO_2 refrigerant is pressurized to be equal to or greater than the critical pressure Pk, it changes into a supercritical state. Thus there is no distinction between a gas phase and a liquid phase in the CO_2 refrigerant. Accordingly, it is possible to optimally control the discharge pressure Pd without unnecessarily increasing it. In other words, it is possible to reduce energy loss.

(3)

[0087] According to the present embodiment, the discharge pressure sensor P1 detects the discharge pressure Pd. Based on this, it is determined if the CO_2 refrigerant of the high pressure side is in a supercritical state or a liquid state. Therefore, it is possible to directly detect the high pressure Ph in the refrigeration cycle based on the discharge pressure Pd. Furthermore, it is possible to proceed to the normal control from the throttle control while a period of time (t2 - t1) necessary for the throttle control is essentially minimized. Consequently, it is possible to optimally control the discharge pressure Pd without unnecessarily increasing it. In other words, it is possible to reduce energy consumption.

(4)

[0088] According to the present embodiment, the outdoor fan 24 or the indoor fan 32, configured to blow air to the outdoor heat exchanger 23 or the indoor heart exchanger 31 functioning as a gas cooler for promoting cooling thereof, is being stopped in the activation of the air conditioning apparatus 1. Therefore, it is possible to weaken a cooling effect on the outdoor heat exchanger 23 or the indoor heat exchanger 31 as much as possible. In other words, it is possible to increase temperature and pressure of the CO_2 refrigerant in the outdoor heat exchanger 23 or the indoor heat exchanger 31. Therefore, it is possible to set the refrigerant at the outlet of the outdoor heat exchanger 23 or the indoor heat exchanger 31 functioning as a gas cooler to be in a supercritical state or a liquid phase state. As a result, it is possible to reduce generation of flow sound of the refrigerant in a vicinity of the inlet of the outdoor expansion valve V2 or the inlet of the indoor expansion valve V5.

(5)

[0089] According to the present embodiment, even at the low external temperature when the external temperature is equal to or less then 20 degrees Celsius, the discharge pressure Pd is controlled to be equal to or greater than the critical pressure Pk by regulating the throttle opening degree θ1 of the outdoor expansion valve V2 or the throttle opening degree θ2 of the indoor expansion valve V5. Therefore, even at the low external temperature when the external temperature is equal to or less than 20 degrees Celsius, it is possible to set the refrigerant to be in a supercritical state or a liquid-phase state.

(6)

[0090] According to the present embodiment, the CO_2 refrigerant is used as refrigerant. The CO_2 refrigerant does not destroy the ozone layer because ozone depletion potential (ODP) thereof equals to zero. Additionally, global warming potential (GWP) of the CO_2 refrigerant equals to 1. This is much lower than GWP of fluorocarbon refrigerant of about hundreds to ten thousand. Accordingly, it is possible to inhibit worsening of the global environment with use of the CO_2 refrigerant with less environmental burden.

<Modifications>

(1)

[0091] According to the present embodiment, the discharge pressure sensor P1 detects the discharge pressure Pd of the compressor 21. It is then determined if the throttle control should be executed based on whether or not the discharge pressure Pd is less than the critical pressure Pk of the CO_2 refrigerant. However, the present invention is not limited to this. The inlet pressure in a vicinity of the inlet of the outdoor expansion valve V2 or the indoor expansion valve V5 may be calculated based on the discharge pressure Pd and the compressor capacity of the compressor 21. Furthermore, it may be determined if the throttle control should be executed based on the inlet pressure.

[0092] The discharge pressure Pd and the inlet pressure of the outdoor expansion valve V2 or the indoor expansion valve V5 are different because of pressure-loss in the refrigerant pipe disposed in the area from the discharge side of the compressor 21 to the outdoor expansion valve V2 or the indoor expansion valve V5. In this case, it is determined if the throttle control should be executed based on the calculated inlet pressure. Therefore, it is possible to more reliably control the gas-liquid two-phase refrigerant in a vicinity of the inlet of the outdoor expansion valve V2 or the inlet of the indoor expansion valve V5, contributing to a cause of noise, to be in a supercritical state or in a liquid-phase state.

(2)

[0093] According to the present embodiment, the discharge pressure sensor P1 detects the discharge pressure Pd of the compressor 21. It is then determined if the throttle control should be executed based on whether or not the discharge pressure Pd is less than the critical pressure Pk of the CO_2 refrigerant. However, the present invention is not limited to this. For example, as illustrated in Fig. 7, a first liquid pipe temperature sensor T2 may be provided in a first liquid refrigerant pipe 28 arranged between the outdoor heat exchanger 23 and the outdoor expansion valve V2. Furthermore, a second liquid pipe temperature sensor T3 may be provided in a second liquid refrigerant pipe 35 arranged between the indoor heat exchanger 31 and the indoor expansion valve V5. With the structure, the inlet temperature in a vicinity of the inlet of the outdoor expansion valve V2 or the indoor expansion valve V5 may be detected, and it may be then determined if the throttle control should be executed based on whether or not the inlet temperature is less than 31 degrees Celsius, that is, the critical temperature of the CO_2 refrigerant.

[0094] Therefore, it is possible to determine if the CO_2 refrigerant is in a supercritical state by detecting the inlet temperature in a vicinity of the inlet of the outdoor expansion valve V2 or the inlet of the indoor expansion valve V5. This makes it possible to determine that the refrigerant in a vicinity of the inlet of the outdoor expansion valve V2 or the inlet of the indoor expansion valve V5 is not in a gas-liquid two-phase state. Consequently, it is possible to reduce blowout sound of bubbles and the like contributing to a cause of flow sound of the refrigerant. Furthermore, it is possible to replace a pressure sensor with a temperature sensor cheaper than the pressure sensor. Accordingly, it is possible to reduce production cost thereof.

(3)

[0095] In the present embodiment, the air conditioning apparatus 1 is exemplified as an apparatus using a refrigeration apparatus. However, the apparatus using a refrigeration apparatus is not limited to this, and may be any suitable apparatus such as a heat-pump water heater and a refrigerator.

INDUSTRIAL APPLICABILITY

[0096] The refrigeration apparatus of the present invention achieves a working effect for inhibiting generation of noise, and is useful as a refrigeration apparatus and the like using refrigerant operating in the supercritical zone.

FURTHER EMBODIMENTS

[0097]

1. A refrigeration apparatus (1) using supercritical refrigerant operating in a zone that high pressure of the supercritical refrigerant is equal to or greater than the critical pressure, the refrigeration apparatus (1) comprising:

a compressor (21) for compressing the supercritical refrigerant;
a gas cooler (23, 31) for cooling the supercritical refrigerant compressed by the compressor (21);
an expansion mechanism (V2, V5) for decompressing the supercritical refrigerant;
an evaporator (31, 23) for evaporating the supercritical refrigerant decompressed by the expansion mechanism (V2, V5);
discharge pressure detection means (PI, T2, T3) being capable of detecting discharge pressure of the compressor (21); and
a control section (5) being configured to regulate an opening degree of the expansion mechanism (V2, V5) for controlling the discharge pressure to be equal to or greater than the supercritical pressure when the refrigeration apparatus (1) is activated and the discharge pressure is less than the critical pressure.

2. The refrigeration apparatus (1) according to 1, wherein the control section (5) is configured to execute a first control for setting the opening degree of the expansion mechanism (V2, V5) to be fully-closed or a slightly-opened degree when the discharge pressure is less than the critical pressure.
3. The refrigeration apparatus (1) according to 2, wherein the control section (5) is configured to execute a second control for setting the opening degree of the expansion mechanism (V2, V5) to be large when the discharge pressure is equal to or greater than the critical pressure after the first control is executed.
4. The refrigeration apparatus (1) according to any of 1 to 3, wherein the discharge pressure detection means is a pressure sensor (PI) provided at the discharge side of the compressor (21).
5. The refrigeration apparatus (1) according to any of 1 to 4, wherein the control section (5) is configured to calculate an inlet pressure of the expansion mechanism (V2, V5) based on the discharge pressure and an operational capacity of the compressor (21) and is configured to regulate the opening degree of the expansion mechanism (V2, V5) for controlling the discharge pressure to be equal to or greater than the critical pressure when the inlet pressure is less than the critical pressure.
6. The refrigeration apparatus (1a), according to any of 1 to 3,
wherein the discharge pressure detection means is a temperature sensor (T2, T3) being capable of detecting temperature of the supercritical refrigerant in a range from an outlet of the gas cooler (23, 31) to an inlet of the expansion mechanism (V2, V5), and
wherein the control section (5) is configured to determine that the inlet pressure could be less than the critical pressure when the inlet temperature is less than the critical temperature and is configured to regulate the opening degree of the expansion mechanism (V2, V5) for controlling the inlet temperature to be equal to or greater than the critical temperature.
7. The refrigeration apparatus (1, 1a) according to any of 1 to 6,
further comprising a blower (24, 32) for promoting cooling of the gas cooler (23, 31), and
wherein the control section (5) is configured to control the airflow volume of the blower (24, 32) to be small or zero when the refrigeration apparatus (1, 1a) is activated and the discharge pressure is less than the critical pressure.
8. The refrigeration apparatus (1, 1a) according to any of 1 to 7, wherein the control section (5) is configured to regulate the opening degree of the expansion mechanism (V2, V5) for controlling the discharge pressure to be equal to or greater than the critical pressure when a normal operation is executed.
9. The refrigeration apparatus (1, 1a) according to any of 1 to 7, wherein the control section (5) is configured to regulate the opening degree of the expansion mechanism (V2, V5) for controlling the discharge pressure to be equal to or greater than the critical pressure even when a normal operation is executed at a low external temperature.
10. The refrigeration apparatus (1, 1a) according to 9, wherein the low external temperature is an external temperature equal to or less than 20 degrees Celsius.
11. A refrigeration apparatus (1, 1 a) using supercritical refrigerant operating in a zone that high pressure of the supercritical refrigerant is equal to or greater than the critical pressure, the refrigeration apparatus (1, 1a) comprising:

a compressor (21) for compressing the supercritical refrigerant;
a gas cooler (23, 31) for cooling the supercritical refrigerant compressed by the compressor (21);
an expansion mechanism (V2, V5) for decompressing the supercritical refrigerant;
an evaporator (31, 23) for evaporating the supercritical refrigerant decompressed by the expansion mechanism (V2, V5);
temperature detection means (T2, T3) being capable of detecting inlet temperature of the expansion mechanism (V2, V5); and
a control section (5) being configured to regulate the opening degree of the expansion mechanism (V2, V5) for controlling the inlet temperature to be equal to or greater than critical tem-

perature when the refrigeration apparatus (1) is activated and the inlet temperature is less than the critical temperature.

12. The refrigeration apparatus (1,1a) according to any of 1 to 11, wherein the supercritical refrigerant is carbon dioxide (CO_2) refrigerant.

Claims

1. A refrigeration apparatus (1, 1a) using supercritical refrigerant operating in a zone that high pressure of the supercritical refrigerant is equal to or greater than the critical pressure, the refrigeration apparatus (1, 1a) comprising:

a compressor (21) for compressing the supercritical refrigerant;
a gas cooler (23, 31) for cooling the supercritical refrigerant compressed by the compressor (21);
an expansion mechanism (V2, V5) for decompressing the supercritical refrigerant;
an evaporator (31, 23) for evaporating the supercritical refrigerant decompressed by the expansion mechanism (V2, V5);
temperature detection means (T2, T3) being capable of detecting inlet temperature of the expansion mechanism (V2, V5); and
a control section (5) being configured to regulate the opening degree of the expansion mechanism (V2, V5) for controlling the inlet temperature to be equal to or greater than the critical temperature when the refrigeration apparatus (1) is activated and the inlet temperature is less than the critical temperature.

2. The refrigeration apparatus (1, 1a) according to claim 1, wherein the supercritical refrigerant is carbon dioxide (CO2) refrigerant and the critical temperature is 31 degrees Celsius.

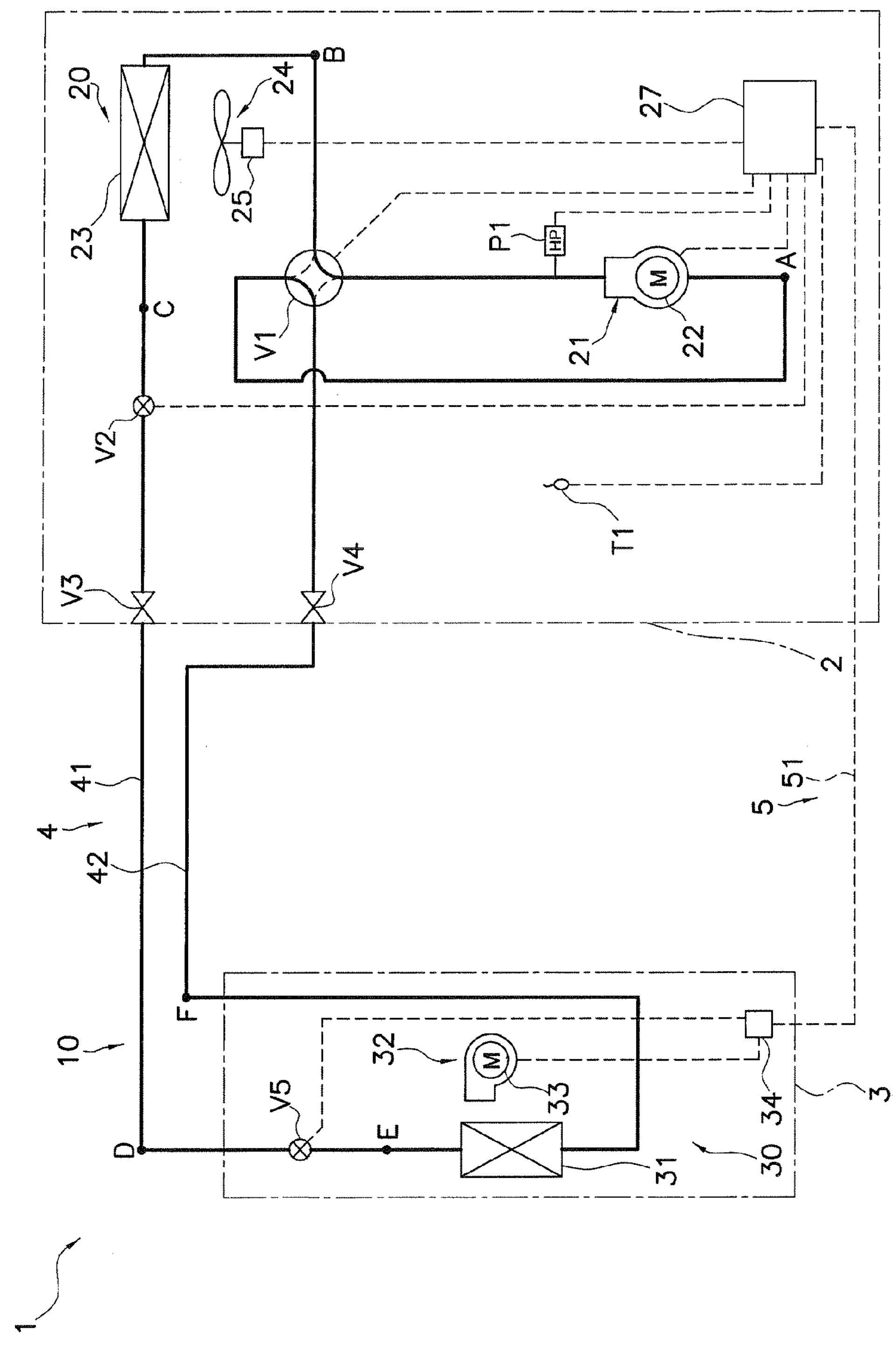
20
23
24
25
27
B
C
V1
V2
P1
HP
M
21
22
A
T1
V3
V4
2
41
42
4
5
51
10
F
D
V5
E
32
33
34
3
30
31
1

FIG. 1

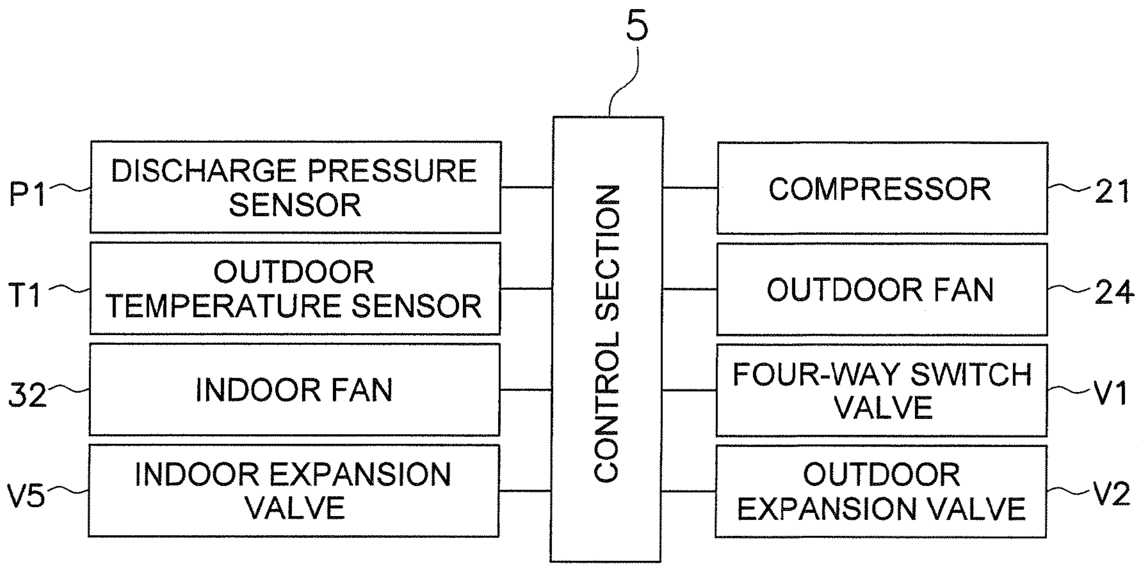
5
DISCHARGE PRESSURE SENSOR
P1
OUTDOOR TEMPERATURE SENSOR
T1
INDOOR FAN
32
INDOOR EXPANSION VALVE
V5
CONTROL SECTION
COMPRESSOR
21
OUTDOOR FAN
24
FOUR-WAY SWITCH VALVE
V1
OUTDOOR EXPANSION VALVE
V2

FIG. 2

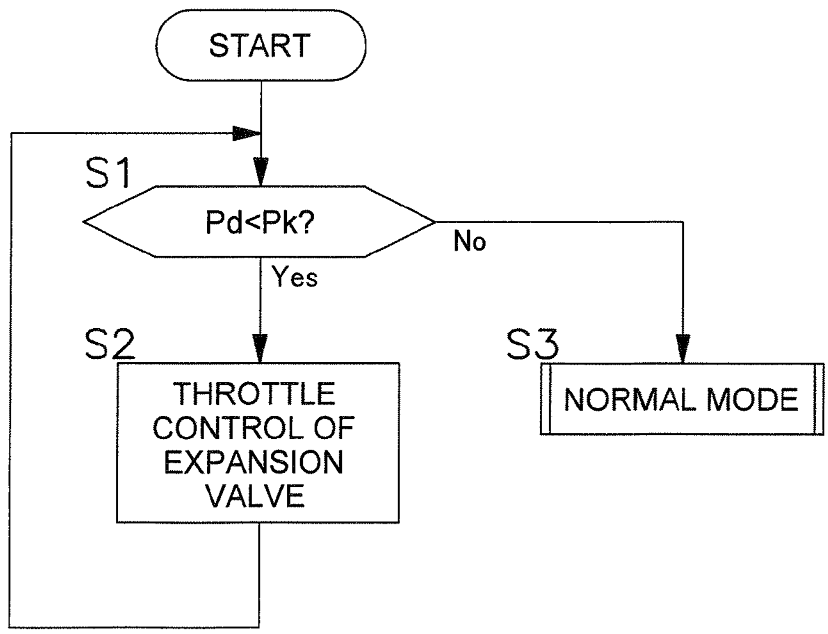
START
S1
Pd<Pk?
Yes
No
S2
THROTTLE CONTROL OF EXPANSION VALVE
S3
NORMAL MODE

FIG. 3

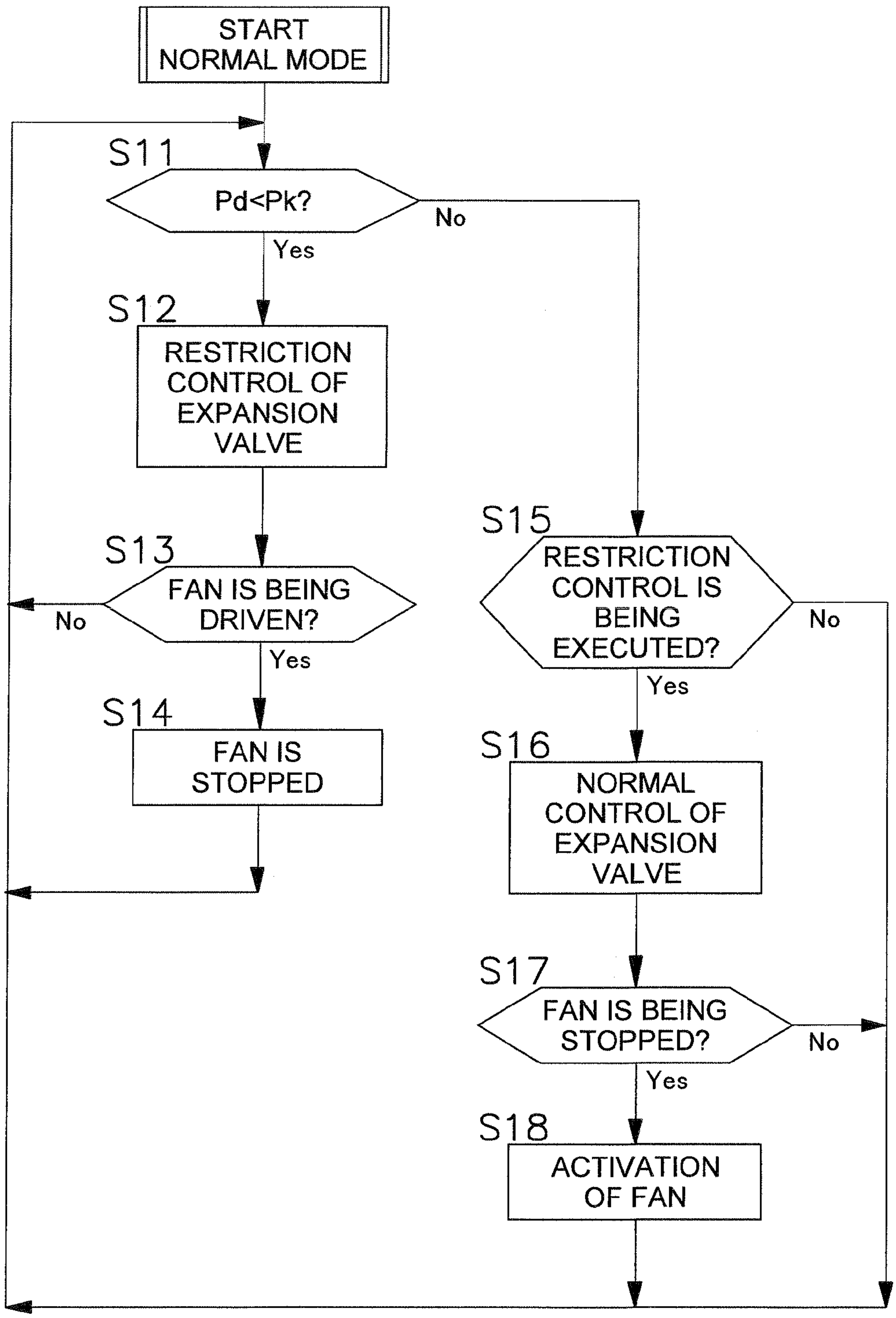
START
NORMAL MODE
S11
Pd<Pk?
No
Yes
S12
RESTRICTION CONTROL OF EXPANSION VALVE
S13
FAN IS BEING DRIVEN?
No
Yes
S14
FAN IS STOPPED
S15
RESTRICTION CONTROL IS BEING EXECUTED?
No
Yes
S16
NORMAL CONTROL OF EXPANSION VALVE
S17
FAN IS BEING STOPPED?
No
Yes
S18
ACTIVATION OF FAN

FIG. 4

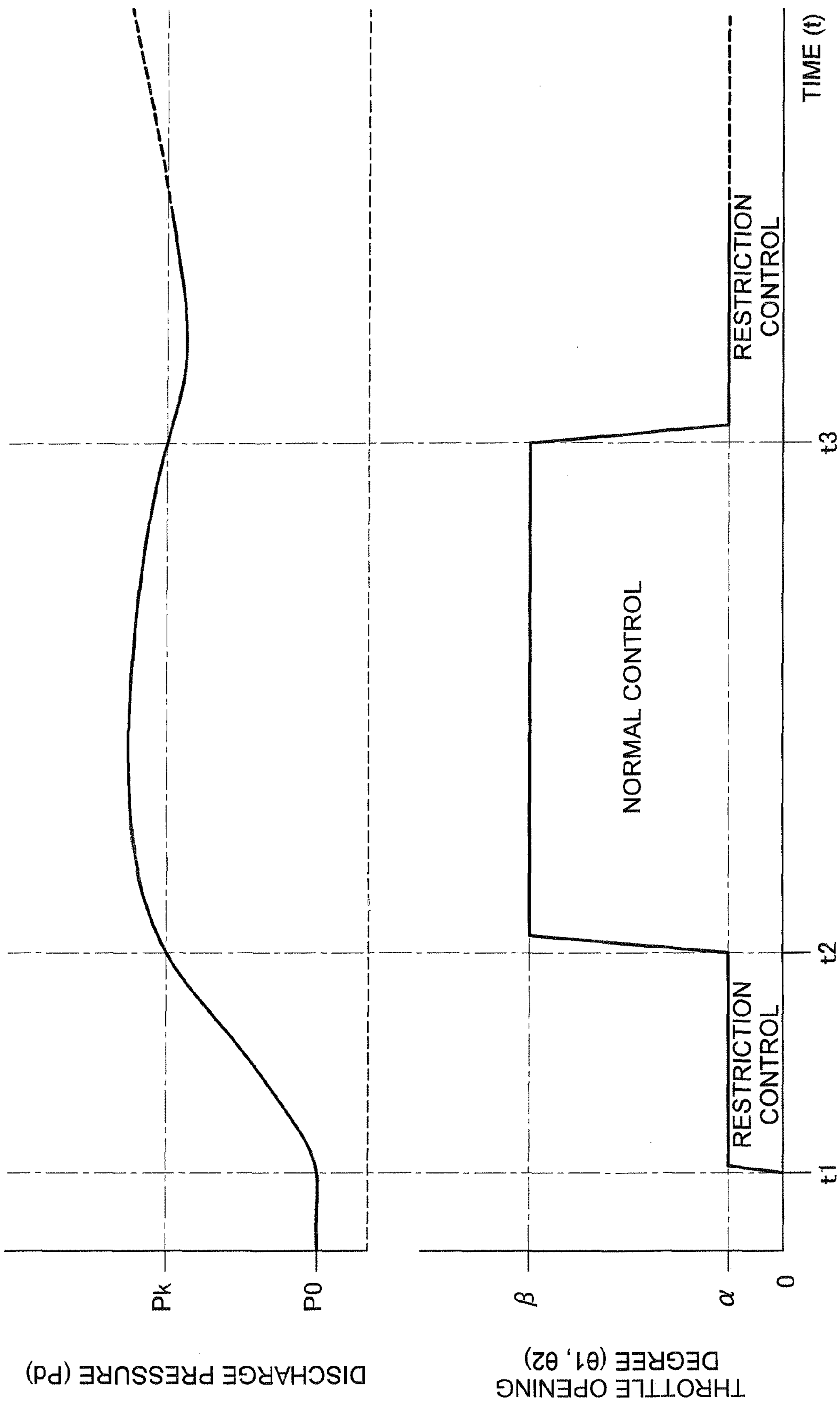
DISCHARGE PRESSURE (Pd)
Pk
P0
THROTTLE OPENING DEGREE (θ1, θ2)
β
α
0
t1
t2
t3
TIME (t)
RESTRICTION CONTROL
NORMAL CONTROL
RESTRICTION CONTROL

FIG. 5

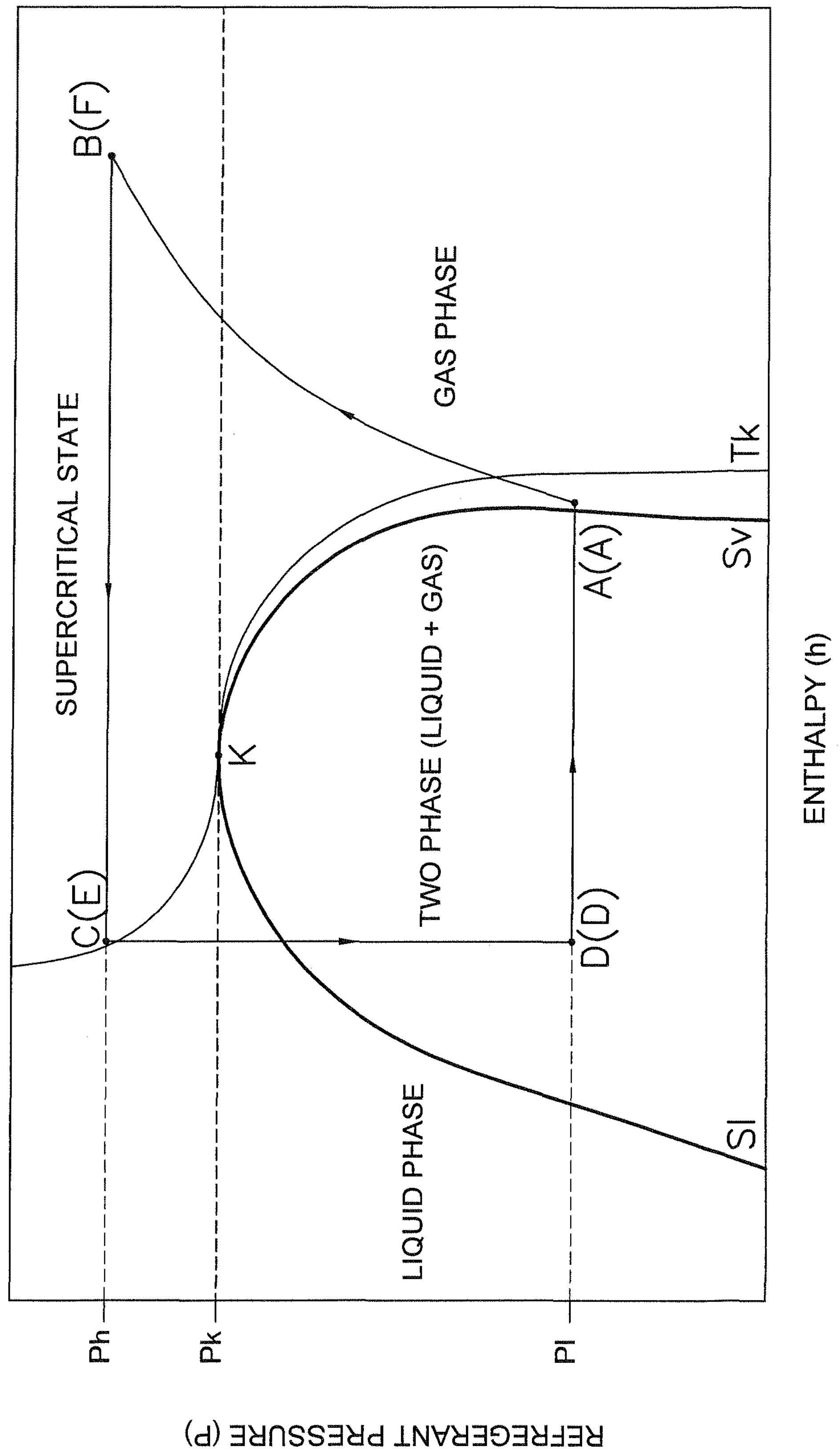
B(F)
GAS PHASE
SUPERCRITICAL STATE
Tk
Sv
A(A)
TWO PHASE (LIQUID + GAS)
K
C(E)
D(D)
LIQUID PHASE
Sl
ENTHALPY (h)
Ph
Pk
Pl
REFREGERANT PRESSURE (P)

FIG. 6

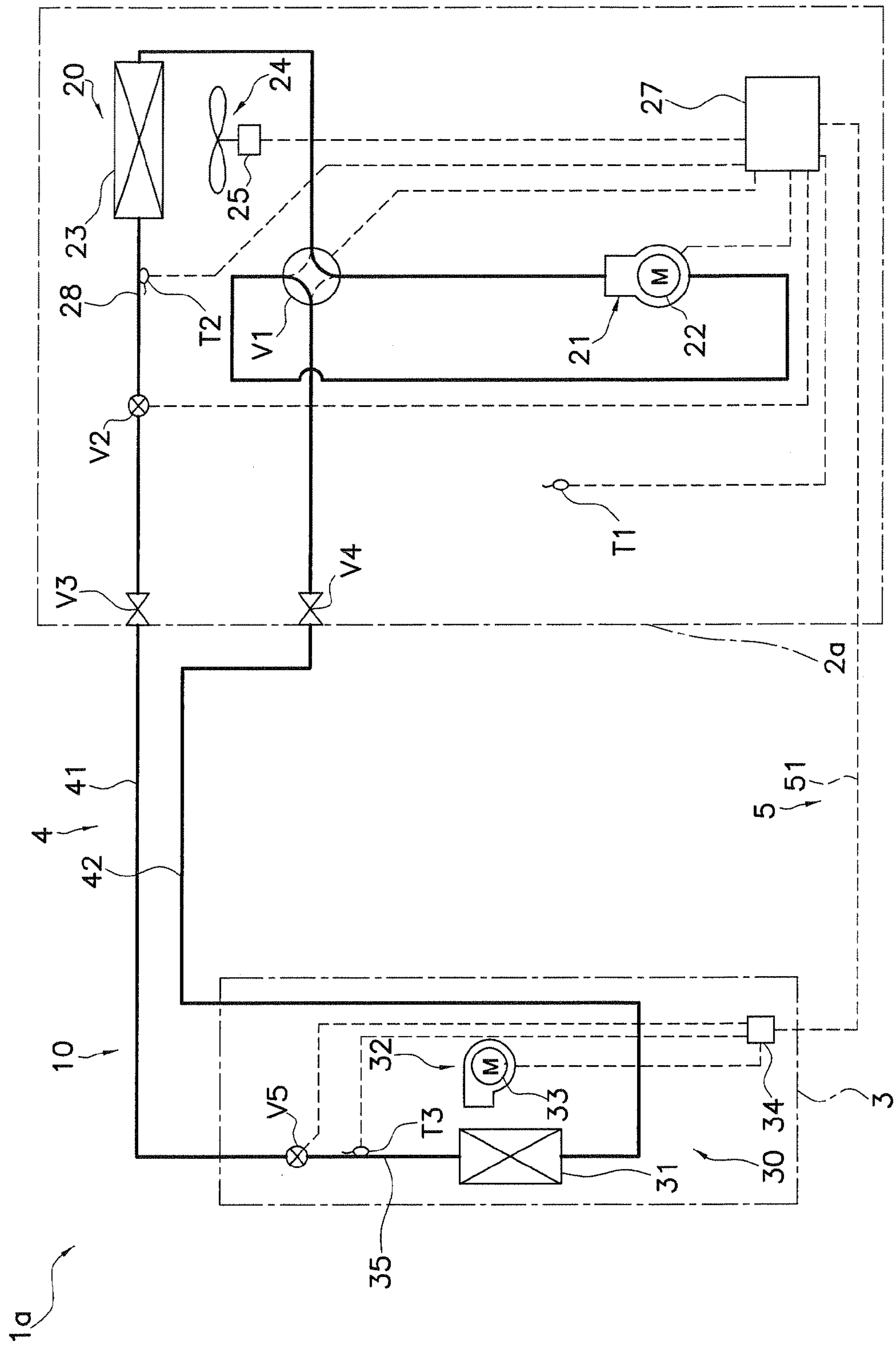
20
24
23
25
27
28
T2
V1
21
22
V2
T1
V3
V4
2a
4
41
42
5
51
10
V5
32
T3
33
34
3
35
31
30
1a
M
M

FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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