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

(11) EP 2 068 093 B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
08.08.2018 Bulletin 2018/32

(21) Application number: **07806192.6**

(22) Date of filing: **29.08.2007**

(51) Int Cl.:
F25B 9/00 *(2006.01)* ***F25B 41/06*** *(2006.01)*

(86) International application number:
PCT/JP2007/066715

(87) International publication number:
WO 2008/032568 (20.03.2008 Gazette 2008/12)

(54) **REFRIGERATION DEVICE**

KÜHLVORRICHTUNG

DISPOSITIF DE RÉFRIGÉRATION

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR

(30) Priority: **11.09.2006 JP 2006246153**

(43) Date of publication of application:
10.06.2009 Bulletin 2009/24

(73) Proprietor: **Daikin Industries, Ltd.**
Osaka 530-8323 (JP)

(72) Inventors:
- **KASAHARA, Shinichi**
Sakai-shi
Osaka 591-8511 (JP)
- **KURIHARA, Toshiyuki**
Sakai-shi
Osaka 591-8511 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(56) References cited:
WO-A1-03/019085
JP-A- 2001 004 235
JP-A- 2001 004 235
JP-A- 2001 133 058
JP-A- 2001 289 537
JP-A- 2001 289 537
US-A- 6 044 655

EP 2 068 093 B1

Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration device, and particularly relates to a refrigeration device in which the refrigerant attains a supercritical state during the refrigeration cycle.

BACKGROUND ART

[0002] Conventional refrigeration devices are widely known that are provided with a refrigerant circuit in which a compressor, a radiator, a first expansion valve, a liquid receiver, a second expansion valve, and an evaporator are connected in sequence (see Patent Documents 1 and 2, for example).

<Patent Document 1>

[0003] Japanese Laid-open Patent Application No. 10-130470 (page 4, fifth column, line 12 through page 5, seventh column, line 39; FIG. 3)

<Patent Document 2>

[0004] WO 03/019085 A1

DISCLOSURE OF THE INVENTION

Technical Problem>

[0005] In a case in which carbon dioxide or another supercritical refrigerant is used as a refrigerant in the refrigerant circuit of such a refrigeration device, when the refrigerant (hereinafter referred to as the high-pressure-side refrigerant) that flows from the refrigerant discharge side of the compressor to the refrigerant inflow side of the first expansion valve has been in a subcritical state since the time operation was started, the high-pressure-side refrigerant sometimes transitions from a supercritical state to a subcritical state when the refrigerant flowing into the radiator has a low temperature, and at other times. When supercooling of the refrigerant that flows out from the radiator is insufficient in this state in which the high-pressure-side refrigerant is in a subcritical state, the refrigerant that flows out from the first expansion valve attains a gas-liquid two-phase state, and it is difficult to control the refrigerant level in the liquid receiver.

[0006] An object of the present invention is to enable the refrigerant level in the liquid receiver to be stably controlled even when the high-pressure-side refrigerant is in a subcritical state in a refrigeration device such as the one described above.

<Solution to Problem>

[0007] A refrigeration device according to a first aspect of the present invention comprises the features as disclosed in claim 1. In this refrigeration device, the control unit minimizes the degree of pressure reduction by the first expansion mechanism when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. Therefore, the refrigerant that flows out from the first expansion mechanism can be made to approach a saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state in this refrigeration device. Consequently, by adopting an appropriate expansion mechanism (in the case of an expansion valve, an expansion valve that has an appropriate maximum degree of opening) in this refrigeration device, it is possible to place the refrigerant that flows out from the first expansion mechanism into a near-saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. It is thereby possible in this refrigeration device to stably control the level of refrigerant in the liquid receiver even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state.

[0008] The refrigeration device further comprises a pressure detector. The pressure detector is provided between the refrigerant discharge side of the compression mechanism and the refrigerant inflow side of the first expansion mechanism. The control unit minimizes the degree of pressure reduction by the first expansion mechanism when the pressure detected by the pressure detector is equal to or less than a predetermined pressure. The "predetermined pressure" referred to herein is the pressure at which the refrigerant attains a subcritical state.

[0009] In this refrigeration device, the control unit minimizes the degree of pressure reduction by the first expansion mechanism when the pressure detected by the pressure detector is equal to or less than a predetermined pressure. It is therefore possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state in this refrigeration device.

[0010] Alternatively, the refrigeration device further comprises a first temperature detector and a second temperature detector. The first temperature detector is provided to a first specific region of the radiator. The term "first specific region" refers to a region in which the high-pressure-side refrigerant is in a gas-liquid two-phase state when the high-pressure-side refrigerant has undergone a transition to a subcritical state. The second temperature detector is provided to the first specific region of the radiator. The control unit minimizes the degree of pressure reduction by the first expansion mechanism when the difference between the temperature detected by the first temperature detector and the temperature detected by the second temperature detector is equal to or less than a predetermined threshold value.

[0011] In this refrigeration device, the control unit minimizes the degree of pressure reduction by the first expansion mechanism when the difference between the temperature detected by the first temperature detector and the temperature detected by the second temperature detector is equal to or less than a predetermined threshold value. It is therefore possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state in this refrigeration device.

[0012] A refrigeration device according to a second aspect of the present invention is the refrigeration device according to the first aspect of the present invention, wherein the first expansion mechanism is a first expansion valve. The control unit fully opens the first expansion valve when the refrigerant that flows from the refrigerant discharge side of the compression mechanism to the refrigerant inflow side of the first expansion mechanism has undergone a transition from a supercritical state to a subcritical state.

[0013] In this refrigeration device, the control unit fully opens the first expansion valve when the refrigerant that flows from the refrigerant discharge side of the compression mechanism to the refrigerant inflow side of the first expansion mechanism has undergone a transition from a supercritical state to a subcritical state. Therefore, the refrigerant that flows out from the first expansion valve can be made to approach a saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state in this refrigeration device. Consequently, by adopting an expansion valve that has an appropriate maximum degree of opening as the first expansion valve in this refrigeration device, it is possible to place the refrigerant that flows out from the first expansion mechanism into a near-saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. It is thereby possible in this refrigeration device to stably control the level of refrigerant in the liquid receiver even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state.

[0014] A refrigeration device according to a third aspect of the present invention is the refrigeration device according to the first aspect of the present invention, wherein the first expansion mechanism is a first expansion valve. The control unit fully opens the first expansion valve when the pressure detected by the pressure detector is equal to or less than a predetermined pressure.

[0015] In this refrigeration device, the control unit fully opens the first expansion valve when the pressure detected by the pressure detector is equal to or less than a predetermined pressure. It is therefore possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state in this refrigeration device.

[0016] A refrigeration device according to a fourth aspect of the present invention is the refrigeration device according to the first aspect of the present invention, wherein the first expansion mechanism is a first expansion valve. The control unit fully opens the first expansion valve when the difference between the temperature detected by the first temperature detector and the temperature detected by the second temperature detector is equal to or less than a predetermined threshold value.

[0017] In this refrigeration device, the control unit fully opens the first expansion valve when the difference between the temperature detected by the first temperature detector and the temperature detected by the second temperature detector is equal to or less than a predetermined threshold value. It is therefore possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state in this refrigeration device.

[0018] A refrigeration device according to a fifth aspect of the present invention is the refrigeration device according to the first aspect of the present invention, further comprising a 30 third temperature detector. The third temperature detector is provided to a second specific region of the radiator. The term "second specific region" refers to a region in which the high-pressure-side refrigerant does not attain a temperature equal to or lower than the critical temperature when the high-pressure-side refrigerant is in a supercritical state, and in which the high-pressure-side refrigerant attains the saturation temperature when the

high-pressure-side refrigerant is in a subcritical state. The control unit minimizes the degree of pressure reduction by the first expansion mechanism when the temperature detected by the third temperature detector is equal to or less than the critical temperature of the refrigerant.

[0019] In this refrigeration device, the control unit minimizes the degree of pressure reduction by the first expansion mechanism when the temperature detected by the third temperature detector is equal to or less than the critical temperature of the refrigerant. It is therefore possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state in this refrigeration device.

[0020] A refrigeration device according to a sixth aspect of the present invention is the refrigeration device according to the fifth aspect of the present invention, wherein the first expansion mechanism is a first expansion valve. The control unit fully opens the first expansion valve when the temperature detected by the third temperature detector is equal to or less than the critical temperature of the refrigerant.

[0021] In this refrigeration device, the control unit fully opens the first expansion valve when the temperature detected by the third temperature detector is equal to or less than the critical temperature of the refrigerant. It is therefore possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state in this refrigeration device.

<Advantageous Effects of Invention>

[0022] In the refrigeration device according to the first aspect, the refrigerant that flows out from the first expansion mechanism can be made to approach a saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. Consequently, by adopting an appropriate expansion mechanism (in the case of an expansion valve, an expansion valve that has an appropriate maximum degree of opening) in this refrigeration device, it is possible to place the refrigerant that flows out from the first expansion mechanism into a near-saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. It is thereby possible in this refrigeration device to stably control the level of refrigerant in the liquid receiver even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. Further, it is easy to determine whether the high-pressure-side refrigerant is in a subcritical state.

[0023] In the refrigeration device according to the second aspect, the refrigerant that flows out from the first expansion valve can be made to approach a saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. Consequently, by adopting an expansion valve that has an appropriate maximum degree of opening as the first expansion valve in this refrigeration device, it is possible to place the refrigerant that flows out from the first expansion mechanism into a near-saturated state even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state. It is thereby possible in this refrigeration device to stably control the level of refrigerant in the liquid receiver even when the high-pressure-side refrigerant has undergone a transition from a supercritical state to a subcritical state.

[0024] In the refrigeration device according to the third through sixth aspects, it is possible to easily determine whether the high-pressure-side refrigerant is in a subcritical state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]

FIG. 1 is a diagram showing the refrigerant circuit of an air conditioning device according to an embodiment of the present invention.

FIG. 2 is a diagram for describing control of the first electric expansion valve when the high-pressure-side refrigerant is in a supercritical state in the air conditioning device according to an embodiment of the present invention.

FIG. 3 is a diagram for describing a state in which the high-pressure-side refrigerant is in a subcritical state in the air conditioning device according to an embodiment of the present invention.

FIG. 4 is a diagram for describing control of the first electric expansion valve when the high-pressure-side refrigerant is in a subcritical state in the air conditioning device according to an embodiment of the present invention.

FIG. 5 is a diagram showing the refrigerant circuit of the air conditioning device according to Modification (A).

FIG. 6 is a diagram for describing control of the first electric expansion valve when the high-pressure-side refrigerant is in a supercritical state in the air conditioning device according to Modification (B).

FIG. 7 is a diagram for describing a state in which the high-pressure-side refrigerant is in a subcritical state in the air conditioning device according to Modification (B).

FIG. 8 is a diagram for describing g control of the first electric expansion valve when the high-pressure-side refrigerant is in a subcritical state in the air conditioning device according to Modification (B).

EXPLANATION OF THE REFERENCE NUMERALS/SYMBOLS/SIGNS

[0026]

1, 101 air conditioning device (refrigeration device)
11 compressor (compression mechanism)
13 outdoor heat exchanger
15 first electric expansion valve (first expansion mechanism)
16 liquid receiver
17, 33a, 33b second electric expansion valve (second expansion mechanism)
21 high-pressure sensor (pressure detector)
23 control device
31, 31a, 31b indoor heat exchanger

BEST MODE FOR CARRYING OUT THE INVENTION

<Structure of air conditioning device>

[0027] FIG. 1 is a schematic view of the refrigerant circuit 2 of the air conditioning device 1 according to an embodiment of the present invention.

[0028] This air conditioning device 1 is an air conditioning device that is capable of cooling operation and heating operation using carbon dioxide as the refrigerant, and is primarily composed of a refrigerant circuit 2, blower fans 26, 32, a control device 23, a high-pressure sensor 21, an intermediate-pressure sensor 24, a temperature sensor 22, and other components.

[0029] The refrigerant circuit 2 is equipped primarily with a compressor 11, a four-way switch valve 12, an outdoor heat exchanger 13, a first electric expansion valve 15, a liquid receiver 16, a second electric expansion valve 17, and an indoor heat exchanger 31, and the devices are connected via a refrigerant pipe, as shown in FIG. 1.

[0030] In the present embodiment, the air conditioning device 1 is a separate-type air conditioning device, and can also be described as comprising an indoor unit 30 primarily having the indoor heat exchanger 31 and an indoor fan 32; an outdoor unit 10 primarily having the compressor 11, the four-way switch valve 12, the outdoor heat exchanger 13, the first electric expansion valve 15, the liquid receiver 16, the second electric expansion valve 17, the high-pressure sensor 21, the temperature sensor 22, and the control device 23; a first connecting pipe 41 for connecting the pipe for refrigerant fluid and the like of the indoor unit 30 and the pipe for refrigerant fluid and the like of the outdoor unit 10; and a second connecting pipe 42 for connecting the pipe for refrigerant gas and the like of the indoor unit 30 and the pipe for refrigerant gas and the like of the outdoor unit 10. The first connecting pipe 41 and the pipe for refrigerant fluid and the like of the outdoor unit 10 are connected via a first close valve 18 of the outdoor unit 10, and the second connecting pipe 42 and the pipe for refrigerant gas and the like of the outdoor unit 10 are connected via a second close valve 19 of the outdoor unit 10.

(1) Indoor unit

[0031] The indoor unit 30 primarily has the indoor heat exchanger 31, the indoor fan 32, and other components.

[0032] The indoor heat exchanger 31 is a heat exchanger for exchanging heat between the refrigerant and the indoor air, which is the air inside the room to be air-conditioned.

[0033] The indoor fan 32 is a fan for taking the air inside the air-conditioned room into the unit 30 and blowing conditioned air, which is the air after heat exchange with the refrigerant via the indoor heat exchanger 31, back into the air-conditioned room.

[0034] Employing such a configuration makes it possible for the indoor unit 30 to cause heat to be exchanged between the indoor air taken in by the indoor fan 32 and the liquid refrigerant that flows through the indoor heat exchanger 31, and generate conditioned air (cool air) during cooling operation, as well as to cause heat to be exchanged between the indoor air taken in by the indoor fan 32 and supercritical refrigerant that flows through the indoor heat exchanger 31, and generate conditioned air (warm air) during heating operation.

(2) Outdoor unit

[0035] The outdoor unit 10 primarily has the compressor 11, the four-way switch valve 12, the outdoor heat exchanger 13, the first electric expansion valve 15, the liquid receiver 16, the second electric expansion valve 17, an outdoor fan 26, the control device 23, the high-pressure sensor 21, the intermediate-pressure sensor 24, the temperature sensor 22, and other components.

[0036] The compressor 11 is a device for sucking in low-pressure refrigerant gas flowing through an intake pipe and compressing the refrigerant gas to a supercritical state, and then discharging the refrigerant to a discharge pipe.

[0037] The four-way switch valve 12 is a valve for switching the flow direction of the refrigerant in accordance with each operation mode, and is capable of connecting the discharge side of the compressor 11 and the high-temperature side of the outdoor heat exchanger 13, and connecting the intake side of the compressor 11 and the gas side of the indoor heat exchanger 31 during cooling operation; as well as connecting the discharge side of the compressor 11 and the second close valve 19, and connecting the intake side of the compressor 11 and the gas side of the outdoor heat exchanger 13 during heating operation.

[0038] The outdoor heat exchanger 13 is capable of cooling the high-pressure supercritical refrigerant discharged from the compressor 11 using the air outside the air-conditioned room as a heat source during cooling operation, and evaporating the liquid refrigerant returning from the indoor heat exchanger 31 during heating operation.

[0039] The first electric expansion valve 15 reduces the pressure of the supercritical refrigerant (during cooling operation) that flows out from the low-temperature side of the outdoor heat exchanger 13, or the liquid refrigerant (during heating operation) that flows in through the liquid receiver 16.

[0040] The liquid receiver 16 stores refrigerant that occurs as excess depending on the operating mode or the air conditioning load.

[0041] The second electric expansion valve 17 reduces the pressure of the liquid refrigerant (during cooling operation) that flows in through the liquid receiver 16, or the supercritical refrigerant (during heating operation) that flows out from the low-temperature side of the indoor heat exchanger 31.

[0042] The outdoor fan 26 is a fan for taking the outdoor air into the unit 10 and discharging the air after heat exchange with the refrigerant via the outdoor heat exchanger 13.

[0043] The high-pressure sensor 21 is provided to the discharge side of the compressor 11.

[0044] The temperature sensor 22 is provided on the outdoor heat exchanger side of the first electric expansion valve 15.

[0045] The intermediate-pressure sensor 24 is provided between the first electric expansion valve 15 and the liquid receiver 16.

[0046] The control device 23 has a communication connection with the high-pressure sensor 21, the intermediate-pressure sensor 24, the temperature sensor 22, the first electric expansion valve 15, the second electric expansion valve 17, and other components, and controls the degree of opening of the first electric expansion valve 15 and the second electric expansion valve 17 on the basis of temperature information transmitted from the temperature sensor 22, high-pressure information transmitted from the high-pressure sensor 21, and intermediate-pressure information transmitted from the intermediate-pressure sensor 24. Control of the degree of opening of the first electric expansion valve 15 and the second electric expansion valve 17 will be described in detail using Mollier diagram.

[0047] When the high pressure information transmitted from the high-pressure sensor 21 indicates a pressure equal to or above the supercritical pressure, the control device 23 determines that the refrigerant (hereinafter referred to as high-pressure-side refrigerant) that flows from the refrigerant discharge side of the compressor 11 to the refrigerant inflow side of the first electric expansion valve 15 is in a supercritical state, and performs first liquid receiver level control and superheating degree control. Since the high-pressure sensor 21 is disposed on the discharge side of the compressor 11, and the temperature sensor 22 is disposed on the outdoor heat exchanger side of the first electric expansion valve 15 in the air conditioning device 1 of the present embodiment, the saturation pressure of the refrigerant that flows out from the first electric expansion valve 15 can be calculated using a Mollier diagram (see FIG. 2). Therefore, during first liquid receiver level control in this air conditioning device 1, the control device 23 appropriately adjusts the degree of opening of the first electric expansion valve 15 and the second electric expansion valve 17 so that the refrigerant that has flowed out from the first electric expansion valve 15 is in the state of point D_0 in FIG. 2; i.e., so that the value indicated by the intermediate-pressure sensor 24 corresponds to the saturation pressure calculated as described above. In FIG. 2, $A_0 \rightarrow B_0$ indicates the compression stroke, $B_0 \rightarrow C_0$ indicates the cooling stroke, $C_0 \rightarrow D_0$ indicates the first expansion stroke (pressure reduction by the first electric expansion valve 15), $D_0 \rightarrow E_0$ indicates the second expansion stroke (pressure reduction by the second electric expansion valve 17), and $E_0 \rightarrow A_0$ indicates the evaporation stroke. Also, K indicates a critical point, and Tm indicates an isothermal line. At this time, since the degree of superheating is also controlled at the same time, the control device 23 concurrently controls the degree of opening of the second electric expansion valve 17. In the present embodiment, the control device 23 controls the first electric expansion valve 15 and the second electric expansion valve 17 so that the pressure indicated by the intermediate-pressure sensor 24 is equal to or lower than the pressure of {critical pressure (MPa) - 0.3 (MPa)}. The pressure of {critical pressure (MPa) - 0.3 (MPa)} is determined in the following manner. The results of tests performed by the inventors show that the pressure (hereinafter referred to as the intermediate pressure) between the first electric expansion valve 15 and the second electric expansion valve 17 can be controlled to within a range of about ± 0.1 MPa from the target value in the case of the refrigerant. In order to prevent the intermediate pressure from coming near the critical point, the target value of the intermediate pressure is preferably the critical pressure (MPa) - 0.3 (MPa), with a safety factor of 3.

[0048] When the high-pressure-side refrigerant attains a subcritical state, the control device 23 performs second liquid receiver level control at the same time as superheating degree control. When the high-pressure-side refrigerant attains a subcritical state, the refrigeration cycle is a refrigeration cycle such as the one indicated by the solid line in FIG. 3. The refrigeration cycle indicated by the dashed line in FIG. 3 is the refrigeration cycle shown in FIG. 2, i.e., the refrigeration cycle that occurs when the high-pressure-side refrigerant is in a supercritical state. As is apparent from FIG. 3, the pressure significantly decreases when the high-pressure-side refrigerant attains a subcritical state. When the control device 23 in this state requires the same degree of opening of the first electric expansion valve 15 as during the first liquid receiver level control, the refrigeration cycle becomes $A_0 \rightarrow B_1 \rightarrow C_1 \rightarrow D_1 \rightarrow E_0 \rightarrow A_0$, the refrigerant that flows out from the first electric expansion valve 15 attains a gas-liquid two-phase state, and it becomes essentially impossible to stabilize the level of refrigerant stored in the liquid receiver 16. Therefore, when the high-pressure information transmitted from the high-pressure sensor 21 indicates a pressure that is less than the critical pressure, i.e., when the high-pressure-side refrigerant is in a subcritical state, the control device 23 performs the second liquid receiver level control in which the first electric expansion valve 15 is fully opened. The refrigeration cycle is then the refrigeration cycle indicated by the solid line in FIG. 4. The refrigeration cycle indicated by the dashed line in FIG. 4 is the refrigeration cycle shown in FIG. 2, i.e., the refrigeration cycle that occurs when the high-pressure-side refrigerant is in a supercritical state. Specifically, since the refrigeration cycle is $A_0 \rightarrow B_1 \rightarrow C_1 \rightarrow D_2 \rightarrow E_0 \rightarrow A_0$, the refrigerant that flows out from the first electric expansion valve 15 is in a near-saturated state. In this air conditioning device 1, the refrigerant level in the liquid receiver is stably controlled in this manner during cooling operation.

<Operation of the air conditioning device>

[0049] The operation of the air conditioning device 1 will be described using FIG. 1. This air conditioning device 1 is capable of cooling operation and heating operation, as described above.

(1) Cooling operation

[0050] During cooling operation, the four-way switch valve 12 is in the state indicated by the solid line in FIG. 1, i.e., a state in which the discharge side of the compressor 11 is connected to the high-temperature side of the outdoor heat exchanger 13, and the intake side of the compressor 11 is connected to the second close valve 19. The first close valve 18 and the second close valve 19 are also open at this time.

[0051] When the compressor 11 is activated in this state of the refrigerant circuit 2, the refrigerant gas is sucked into the compressor 11 and compressed to a supercritical state, and then sent through the four-way switch valve 12 to the outdoor heat exchanger 13 and cooled in the outdoor heat exchanger 13.

[0052] This cooled supercritical refrigerant is sent to the first electric expansion valve 15. The supercritical refrigerant sent to the first electric expansion valve 15 is depressurized to a saturated state, and then sent to the second electric expansion valve 17 via the liquid receiver 16. The refrigerant in a saturated state sent to the second electric expansion valve 17 is depressurized to liquid refrigerant, and then fed to the indoor heat exchanger 31 via the first close valve 18, where the refrigerant cools the indoor air and evaporates into refrigerant gas.

[0053] The refrigerant gas is again sucked into the compressor 11 via the second close valve 19, the internal heat exchanger 14, and the four-way switch valve 12. Cooling operation is performed in this manner. The control device 23 performs the control described above in this cooling operation.

(2) Heating operation

[0054] During heating operation, the four-way switch valve 12 is in the state indicated by the dashed line in FIG. 1, i.e., a state in which the discharge side of the compressor 11 is connected to the second close valve 19, and the intake side of the compressor 11 is connected to the gas side of the outdoor heat exchanger 13. The first close valve 18 and the second close valve 19 are also open at this time.

[0055] When the compressor 11 is activated in this state of the refrigerant circuit 2, the refrigerant gas is sucked into the compressor 11 and compressed to a supercritical state, and then is fed to the indoor heat exchanger 31 via the four-way switch valve 12 and the second close valve 19.

[0056] The supercritical refrigerant heats the indoor air, and is cooled in the indoor heat exchanger 31. The cooled supercritical refrigerant is sent through the first close valve to the second electric expansion valve 17. The supercritical refrigerant sent to the second electric expansion valve 17 is depressurized to a saturated state, and then sent to the first electric expansion valve 15 via the liquid receiver 16. The refrigerant in a saturated state sent to the first electric expansion valve 15 is depressurized to liquid refrigerant, and then sent to the outdoor heat exchanger 13 via the internal heat exchanger 14 and evaporated to refrigerant gas in the outdoor heat exchanger 13. This refrigerant gas is again sucked into the compressor 11 via the four-way switch valve 12. Heating operation is performed in this manner.

<Characteristics of the air conditioning device>

[0057] In the air conditioning device 1 according to the present embodiment, the control device 23 is capable of fully opening the first electric expansion valve 15 and placing the refrigerant that flows out from the first electric expansion valve 15 in a near-saturated state when the high-pressure information transmitted from the high-pressure sensor 21 indicates a pressure that is less than the critical pressure, i.e., when the high-pressure-side refrigerant is in a subcritical state. The refrigerant level in the liquid receiver can therefore be stably controlled even when the high-pressure-side refrigerant is in a subcritical state.

<Modifications>

(A)

[0058] In the embodiment described above, the invention of the present application is applied to a separate-type air conditioning device 1 in which one indoor unit 30 is provided for one outdoor unit 10, but the invention of the present application may also be applied to a multi-type air conditioning device 101 in which a plurality of indoor units is provided for one outdoor unit, such as shown in FIG. 5. In FIG. 5, the same reference numerals are used to refer to components that are the same as those of the air conditioning device 1 according to the embodiment described above. In FIG. 5, the reference numeral 102 refers to a refrigerant circuit, 110 refers to an outdoor unit, 130a and 130b refer to indoor units, 31a and 31b refer to indoor heat exchangers, 32a and 32b refer to indoor fans, 33a and 33b refer to second electric expansion valves, 34a and 34b refer to indoor control devices, and 141 and 142 refer to connecting ducts. In this case, the control device 23 controls the second electric expansion valves 33a, 33b via the indoor control devices 34a, 34b. The second electric expansion valves 33a, 33b are housed in the indoor units 130a, 130b in the present modification, but the second electric expansion valves 33a, 33b may also be housed in the outdoor unit 110.

(B)

[0059] In the air conditioning device 1 according to the embodiment described above, although not particularly mentioned in the above description, a supercooling heat exchanger (which may be an internal heat exchanger) may be provided between the liquid receiver 16 and the second electric expansion valve 17. In this case, in the first liquid receiver level control, the degree of opening of the first electric expansion valve 15 is controlled by the control device 23 so that a refrigeration cycle such as the one shown in FIG. 6 is executed. In FIG. 6, $A_0 \rightarrow B_0$ indicates the compression stroke, $B_0 \rightarrow C_0$ indicates the cooling stroke, $C_0 \rightarrow D_0$ indicates the first expansion stroke (pressure reduction by the first electric expansion valve 15), $D_0 \rightarrow F_0$ indicates the supercooling stroke (cooling by the supercooling heat exchanger), $F_0 \rightarrow E_3$ indicates the second expansion stroke (pressure reduction by the second electric expansion valve 17), and $E_3 \rightarrow A_0$ indicates the evaporation stroke. Also, K indicates a critical point, and Tm indicates an isothermal line. In other words, in this first liquid receiver level control, the control device 23 controls the degree of opening of the first electric expansion valve 15 so that the refrigerant that flows out from the first electric expansion valve 15 attains a saturated state.

[0060] In the second liquid receiver level control, the refrigeration cycle is a refrigeration cycle such as indicated by the solid line in FIG. 7, and when the control device 23 in this state requires the same degree of opening of the first electric expansion valve 15 as during the liquid receiver level control, the refrigeration cycle becomes $A_0 \rightarrow B_1 \rightarrow C_1 \rightarrow D_1 \rightarrow F_1 \rightarrow E_3 \rightarrow A_0$, the refrigerant that flows out from the first electric expansion valve 15 attains a gas-liquid two-phase state, and it becomes essentially impossible to stabilize the level of refrigerant stored in the liquid receiver 16. Therefore, when the high-pressure information transmitted from the high-pressure sensor 21 indicates a pressure that is less than the critical pressure, i.e., when the high-pressure-side refrigerant is in a subcritical state, the control device 23 causes the first electric expansion valve 15 to be fully open. The refrigeration cycle is then the refrigeration cycle indicated by the solid line in FIG. 8. Specifically, since the refrigeration cycle is $A_0 \rightarrow B_1 \rightarrow C_1 \rightarrow D_0 \rightarrow F_0 \rightarrow E_3 \rightarrow A_0$, the refrigerant that flows out from the first electric expansion valve 15 is in a near-saturated state. In this air conditioning device 1, the refrigerant level in the liquid receiver is stably controlled in this manner during cooling operation.

(C)

[0061] In the air conditioning device 1 according to the embodiment described above, the first electric expansion valve 15, the liquid receiver 16, the second electric expansion valve 17, and other components are disposed in the outdoor unit 10, but the positioning of these components is not particularly limited. For example, the second electric expansion valve 17 may be disposed in the indoor unit 30.

(D)

[0062] An electric expansion valve is used as the means for reducing the pressure of the refrigerant in the air conditioning device 1 according to the embodiment described above, but an expansion device or the like may instead be used.

(E)

[0063] Although not particularly mentioned in the air conditioning device 1 according to the embodiment described above, the liquid receiver 16 and the intake pipe of the compressor 11 may be connected to form a gas release circuit. In this case, an electric expansion valve, an electromagnetic valve, or the like is preferably provided to the gas release circuit.

(F)

[0064] The intermediate-pressure sensor 24 is provided in the air conditioning device 1 according to the embodiment described above, but the intermediate-pressure sensor 24 may also be omitted. In this case, during the first liquid receiver level control, the total degree of opening of the first electric expansion valve 15 and the second electric expansion valve 17 may be expressed as a function in advance using the degree of superheating in the intake pipe of the compressor 11 as the variable, for example, or a control table may be created that shows the relationship of the total degree of opening and the degree of superheating, and the ratio of the degree of opening of the first electric expansion valve 15 and the second electric expansion valve 17 may thereby be expressed as a function in advance using the high pressure and the entry temperature of the first electric expansion valve as variables. The degree of opening of the first electric expansion valve 15 and the second electric expansion valve 17 can thereby be uniquely determined.

(G)

[0065] In the air conditioning device 1 according to the embodiment described above, the transition of the high-pressure-side refrigerant from a supercritical state to a subcritical state is detected by the high-pressure sensor 21. However, the transition of the high-pressure-side refrigerant from a supercritical state to a subcritical state may be detected by another method. For example, two temperature sensors may be provided to the region in which the high-pressure-side refrigerant attains a gas-liquid two-phase state when the high-pressure-side refrigerant undergoes a transition to a subcritical state, i.e., a specific region of the heat transfer tube of the radiator, and it can be determined that the high-pressure-side refrigerant has undergone a transition to a subcritical state when the temperature information obtained from the two temperature sensors is substantially the same (e.g., the temperature information is determined to be substantially the same when the difference between the sets of temperature information is equal to or smaller than a predetermined threshold value). A temperature sensor may also be provided in a region in which the high-pressure-side refrigerant does not reach a temperature equal to or lower than the critical temperature when the high-pressure-side refrigerant is in a supercritical state, and in which the high-pressure-side refrigerant reaches the saturation temperature when the high-pressure-side refrigerant is in a subcritical state, i.e., a specific region of the heat transfer tube of the radiator, for example, and a determination can be made that the high-pressure-side refrigerant has undergone a transition to the subcritical state when the temperature information obtained from the temperature sensor indicates a temperature that is equal to or lower than the critical temperature. A single temperature sensor is adequate in this case.

INDUSTRIAL APPLICABILITY

[0066] The refrigeration device of the present invention has the characteristic of enabling the refrigerant level in the liquid receiver to be stably controlled, and the present invention is particularly useful in a refrigeration device in which carbon dioxide or the like is used as the refrigerant.

Claims

1. A refrigeration device (1, 101) comprising:

a compression mechanism (11) configured to compress a refrigerant;
a radiator (13) connected to a refrigerant discharge side of said compression mechanism;
a first expansion mechanism (15) connected to an exit side of said radiator;
a liquid receiver (16) connected to a refrigerant outflow side of said first expansion mechanism;
a second expansion mechanism (17, 33a, 33b) connected to an exit side of said liquid receiver;
an evaporator (31, 31a, 31b) connected to a refrigerant outflow side of said second expansion mechanism and to a refrigerant intake side of said compression mechanism; and
a control unit (23) for minimizing the degree of pressure reduction by said first expansion mechanism when the refrigerant that flows from the refrigerant discharge side of said compression mechanism to a refrigerant inflow side of said first expansion mechanism has undergone a transition from a supercritical state to a subcritical state,
characterized in that said refrigeration device further comprises
a pressure detector (21) provided between the refrigerant discharge side of said compression mechanism and the refrigerant inflow side of said first expansion mechanism, wherein said control unit (23) is configured to minimize the degree of pressure reduction by said first expansion mechanism when the pressure detected by said pressure detector is equal to or less than a predetermined pressure; or
in that the refrigeration device further comprises a first temperature detector provided to a first specific region of said radiator; and
a second temperature detector provided to said first specific region of said radiator, wherein said control unit (23) is configured to minimize the degree of pressure reduction by said first expansion mechanism when the difference between the temperature detected by said first temperature detector and the temperature detected by said second temperature detector is equal to or less than a predetermined threshold value.

2. The refrigeration device according to claim 1, wherein

said first expansion mechanism is a first expansion valve; and
said control unit fully opens said first expansion valve when the refrigerant that flows from the refrigerant discharge side of said compression mechanism to the refrigerant inflow side of said first expansion mechanism has undergone a transition from a supercritical state to a subcritical state.

3. The refrigeration device according to claim 1, wherein

said first expansion mechanism is a first expansion valve; and
said control unit fully opens said first expansion valve when the pressure detected by said pressure detector is equal to or less than a predetermined pressure.

4. The refrigeration device according to claim 1, wherein

said first expansion mechanism is a first expansion valve; and
said control unit fully opens said first expansion valve when the difference between the temperature detected by said first temperature detector and the temperature detected by said second temperature detector is equal to or less than a predetermined threshold value.

5. The refrigeration device according to claim 1, further comprising:

a third temperature detector provided to a second specific region of said radiator; wherein
said control unit minimizes the degree of pressure reduction by said first expansion mechanism when the temperature detected by said third temperature detector is equal to or less than the critical temperature of said refrigerant.

6. The refrigeration device according to claim 5, wherein

said first expansion mechanism is a first expansion valve; and
said control unit fully opens said first expansion valve when the temperature detected by said third temperature detector is equal to or less than the critical temperature of said refrigerant.

Patentansprüche

1. Kältegerät (1, 101), umfassend:

einen Kompressionsmechanismus (11), der derart konfiguriert ist, um ein Kältemittel zu komprimieren;
einen Kühler (13), der an einer Kältemittel-Ablassseite des Kompressionsmechanismus angeschlossen ist;
einen ersten Expansionsmechanismus (15), der an einer Ausgangsseite des Kühlers angeschlossen ist;
einen Flüssigkeitstank (16), der an einer Kältemittel-Ausflussseite des ersten Expansionsmechanismus angeschlossen ist;
einen zweiten Expansionsmechanismus (17, 33a, 33b), die an einer Ausgangsseite des Flüssigkeitstanks angeschlossen ist;
einen Verdampfer (31, 31a, 31b), der an einer Kältemittel-Ausflussseite des zweiten Expansionsmechanismus und an einer Kältemittel-Einlassseite des Kompressionsmechanismus angeschlossen ist; und
eine Steuereinheit (23) zum Reduzieren des Ausmaßes eines Druckabfalls durch den ersten Expansionsmechanismus, wenn sich das Kältemittel, das von der Kältemittel-Ablassseite des Kompressionsmechanismus zu einer Kältemittel-Einflussseite des ersten Expansionsmechanismus strömt, einem Übergang von einem überkritischen Zustand in einen subkritischen Zustand unterzogen hat,
dadurch gekennzeichnet, dass das Kältegerät weiter Folgendes umfasst
einen Druckdetektor (21), der zwischen der Kältemittel-Ablassseite des Kompressionsmechanismus und der Kältemittel-Einflussseite des ersten Expansionsmechanismus bereitgestellt ist, wobei die Steuereinheit (23) derart konfiguriert ist, um das Ausmaß eines Druckabfalls durch den ersten Expansionsmechanismus zu reduzieren, wenn der von dem Druckdetektor detektierte Druck kleiner oder gleich einem vorbestimmten Druck ist; oder
dadurch, dass das Kältegerät weiter Folgendes umfasst
einen ersten Temperaturdetektor, der in einer ersten spezifischen Region des Kühlers bereitgestellt ist; und
einen zweiten Temperaturdetektor, der in der ersten spezifischen Region des Kühlers bereitgestellt ist, wobei die Steuereinheit (23) derart konfiguriert ist, um das Ausmaß eines Druckabfalls durch den ersten Expansionsmechanismus zu reduzieren, wenn der Unterschied zwischen der von dem ersten Temperaturdetektor detektierten Temperatur und der von dem zweiten Temperaturdetektor detektierten Temperatur kleiner oder gleich einem vorbestimmten Grenzwert ist.

2. Kältegerät nach Anspruch 1, wobei
der erste Expansionsmechanismus ein erstes Expansionsventil ist; und
die Steuereinheit das erste Expansionsventil vollständig öffnet, wenn sich das Kältemittel, das von der Kältemittel-Ablassseite des Kompressionsmechanismus zu der Kältemittel-Einflussseite des ersten Expansionsmechanismus strömt, einem Übergang von einem überkritischen Zustand in einen subkritischen Zustand unterzogen hat.

3. Kältegerät nach Anspruch 1, wobei
der erste Expansionsmechanismus ein erstes Expansionsventil ist; und
die Steuereinheit das erste Expansionsventil vollständig öffnet, wenn der von dem Druckdetektor detektierte Druck kleiner oder gleich einem vorbestimmten Druck ist.

4. Kältegerät nach Anspruch 1, wobei
der erste Expansionsmechanismus ein erstes Expansionsventil ist; und
die Steuereinheit das erste Expansionsventil vollständig öffnet, wenn der Unterschied zwischen der von dem ersten Temperaturdetektor detektierten Temperatur und der von dem zweiten Temperaturdetektor detektierten Temperatur kleiner oder gleich einem vorbestimmten Grenzwert ist.

5. Kältegerät nach Anspruch 1, weiter umfassend:

einen dritten Temperaturdetektor, der in einer zweiten spezifischen Region des Kühlers bereitgestellt ist; wobei
die Steuereinheit das Ausmaß eines Druckabfalls durch den ersten Expansionsmechanismus minimiert, wenn die von dem dritten Temperaturdetektor detektierte Temperatur kleiner oder gleich der kritischen Temperatur des Kältemittels ist.

6. Kältegerät nach Anspruch 5, wobei
der erste Expansionsmechanismus ein erstes Expansionsventil ist; und
die Steuereinheit das erste Expansionsventil vollständig öffnet, wenn die von dem dritten Temperaturdetektor detektierte Temperatur kleiner oder gleich der kritischen Temperatur des Kältemittels ist.

Revendications

1. Dispositif de réfrigération (1, 101) comprenant :

un mécanisme de compression (11) configuré pour compresser un réfrigérant ;
un radiateur (13) raccordé à un côté de décharge de réfrigérant dudit mécanisme de compression ;
un premier mécanisme d'expansion (15) raccordé à un côté de sortie dudit radiateur ;
un récepteur de liquide (16) raccordé à un côté de sortie de réfrigérant dudit premier mécanisme d'expansion ;
un second mécanisme d'expansion (17, 33a, 33b) raccordé à un côté de sortie dudit récepteur de liquide ;
un évaporateur (31, 31a, 31b) raccordé à un côté de sortie de réfrigérant dudit second mécanisme d'expansion et à un côté d'entrée de réfrigérant dudit mécanisme de compression ; et
une unité de commande (23) pour la minimisation du degré de réduction de pression par ledit premier mécanisme d'expansion lorsque le réfrigérant qui s'écoule du côté de décharge de réfrigérant dudit mécanisme de compression à un côté d'entrée de réfrigérant dudit premier mécanisme d'expansion a subi une transition d'un état supercritique à un état sous-critique,
caractérisé en ce que ledit dispositif de réfrigération comprend en outre
un détecteur de pression (21) prévu entre le côté de décharge de réfrigérant dudit mécanisme de compression et le côté d'entrée de réfrigérant dudit premier mécanisme d'expansion, dans lequel ladite unité de commande (23) est configurée pour minimiser le degré de réduction de pression par ledit premier mécanisme d'expansion lorsque la pression détectée par ledit détecteur de pression est égale ou inférieure à une pression prédéterminée ; ou
en ce que le dispositif de réfrigération comprend en outre
un premier détecteur de température prévu sur une première région spécifique dudit radiateur ; et
un deuxième détecteur de température prévu sur ladite première région spécifique dudit radiateur, dans lequel ladite unité de commande (23) est configurée pour minimiser le degré de réduction de pression par ledit premier mécanisme d'expansion lorsque la différence entre la température détectée par ledit premier détecteur de température et la température détectée par ledit deuxième détecteur de température est égale ou inférieure à une valeur seuil prédéterminée.

2. Dispositif de réfrigération selon la revendication 1, dans lequel ledit premier mécanisme d'expansion est une première valve d'expansion ; et ladite unité de commande ouvre complètement ladite première valve d'expansion lorsque le réfrigérant qui s'écoule du côté de décharge de réfrigérant dudit mécanisme de compression au côté d'entrée de réfrigérant dudit premier mécanisme d'expansion a subi une transition d'un état supercritique à un état sous-critique.

3. Dispositif de réfrigération selon la revendication 1, dans lequel ledit premier mécanisme d'expansion est une première valve d'expansion ; et ladite unité de commande ouvre complètement ladite première valve d'expansion lorsque la pression détectée par ledit détecteur de pression est égale ou inférieure à une pression prédéterminée.

4. Dispositif de réfrigération selon la revendication 1, dans lequel ledit premier mécanisme d'expansion est une première valve d'expansion ; et ladite unité de commande ouvre complètement ladite première valve d'expansion lorsque la différence entre la température détectée par ledit premier détecteur de température et la température détectée par ledit deuxième détecteur de température est égale ou inférieure à une valeur seuil prédéterminée.

5. Dispositif de réfrigération selon la revendication 1, comprenant en outre :

un troisième détecteur de température prévu sur une seconde région spécifique dudit radiateur ; dans lequel
ladite unité de commande minimise le degré de réduction de pression par ledit premier mécanisme d'expansion lorsque la température détectée par ledit troisième détecteur de température est égale ou inférieure à la température critique dudit réfrigérant.

6. Dispositif de réfrigération selon la revendication 5, dans lequel ledit premier mécanisme d'expansion est une première valve d'expansion ; et ladite unité de commande ouvre complètement ladite première valve d'expansion lorsque la température détectée par ledit troisième détecteur de température est égale ou inférieure à la température critique dudit réfrigérant.

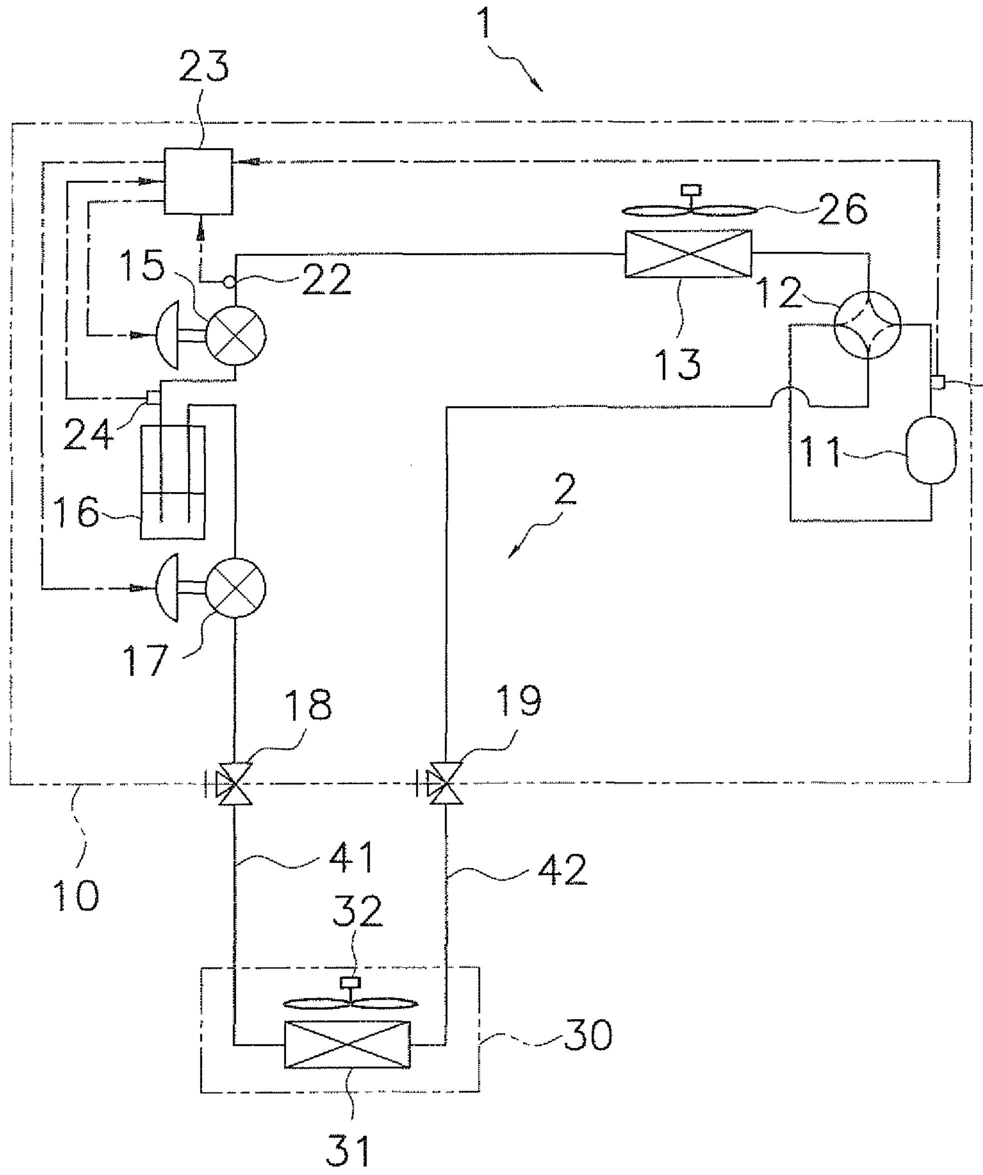

FIG. 1

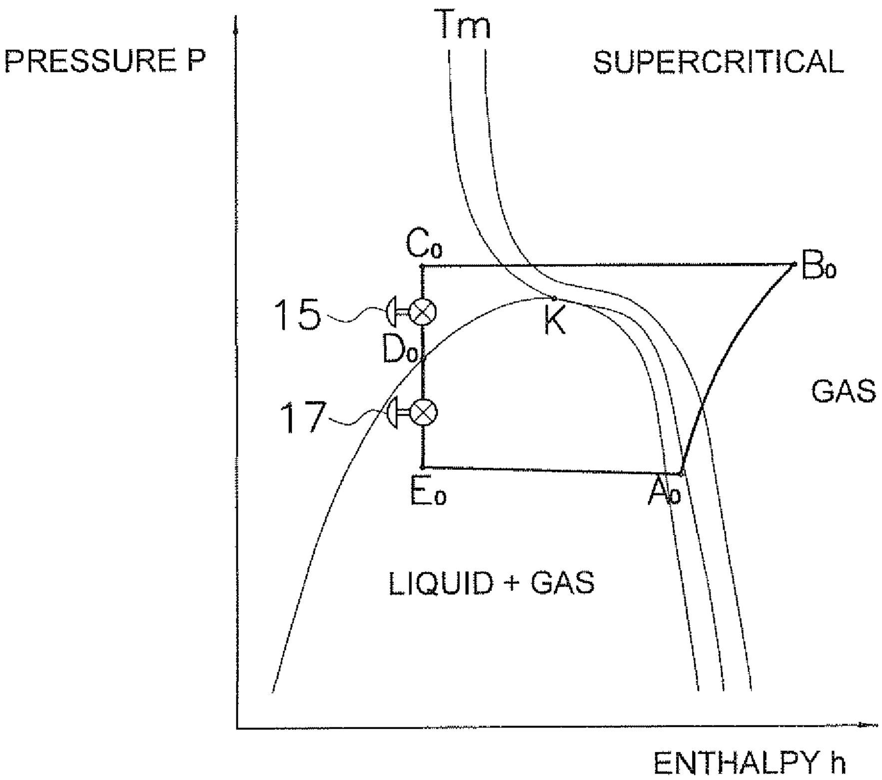
PRESSURE P
Tm
SUPERCRITICAL
C0
B0
15
K
D0
GAS
17
E0
A0
LIQUID + GAS
ENTHALPY h

FIG. 2

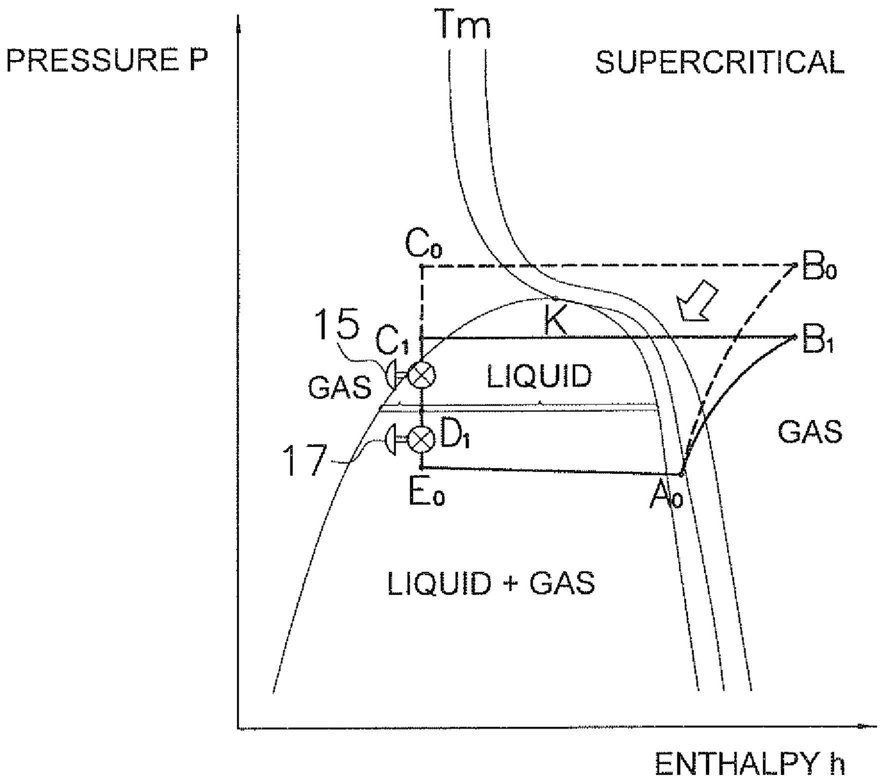
PRESSURE P
Tm
SUPERCRITICAL
C0
B0
K
15
C1
B1
GAS
LIQUID
GAS
D1
17
E0
A0
LIQUID + GAS
ENTHALPY h

FIG. 3

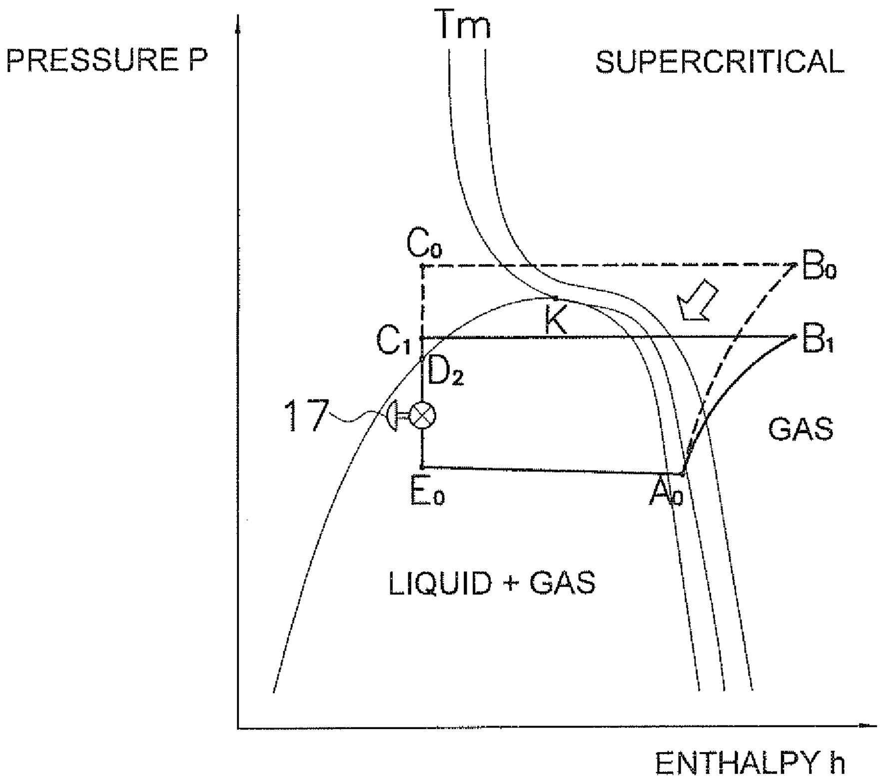
PRESSURE P
Tm
SUPERCRITICAL
C0
B0
K
C1
B1
D2
17
GAS
E0
A0
LIQUID + GAS
ENTHALPY h

FIG. 4

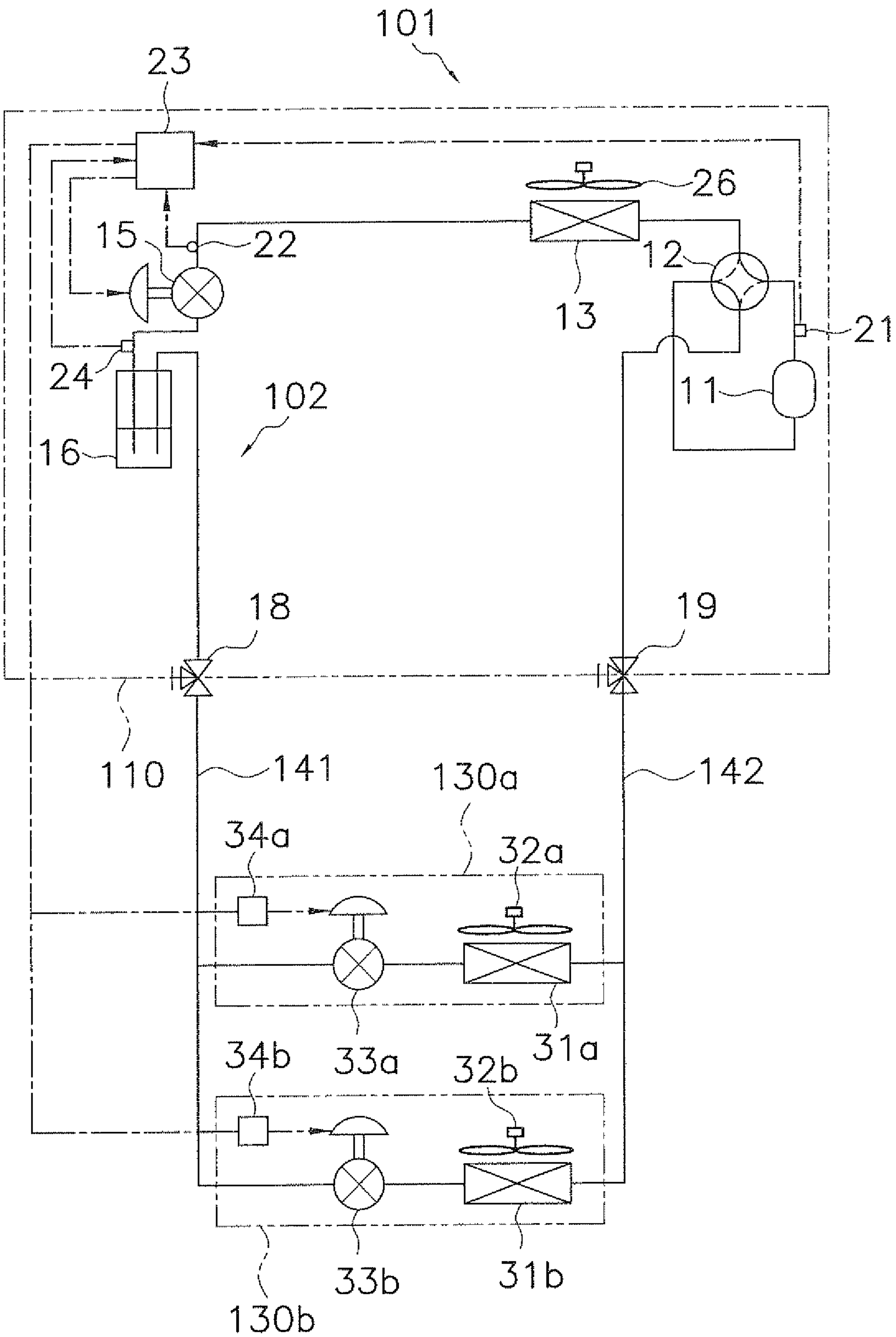
101
23
26
15
22
12
21
13
24
11
102
16
18
19
110
141
142
130a
34a
32a
33a
31a
34b
32b
33b
31b
130b

FIG. 5

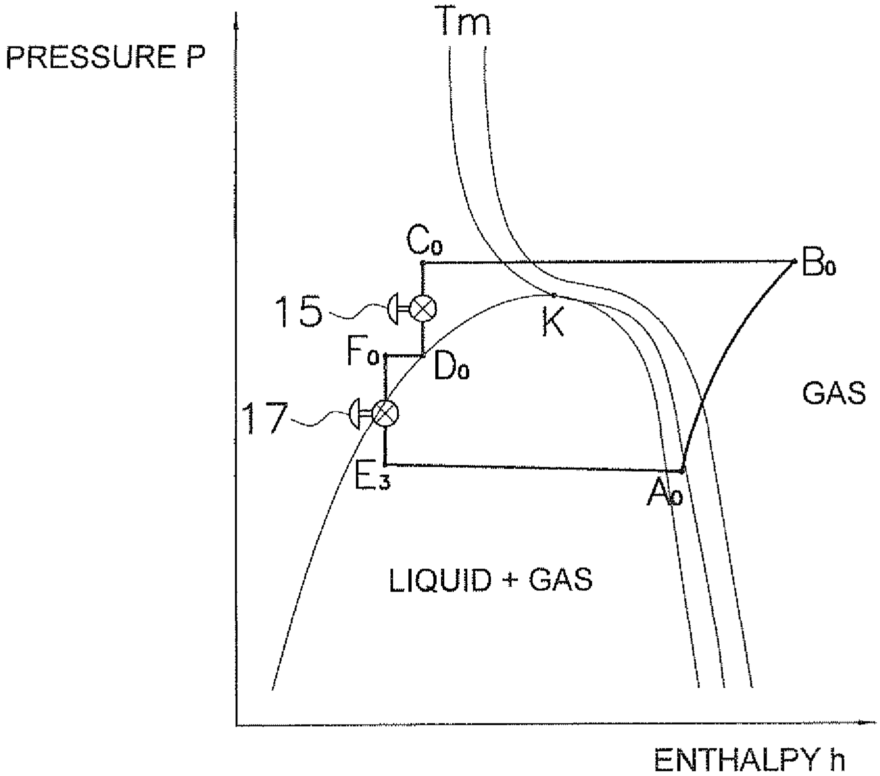

FIG. 6

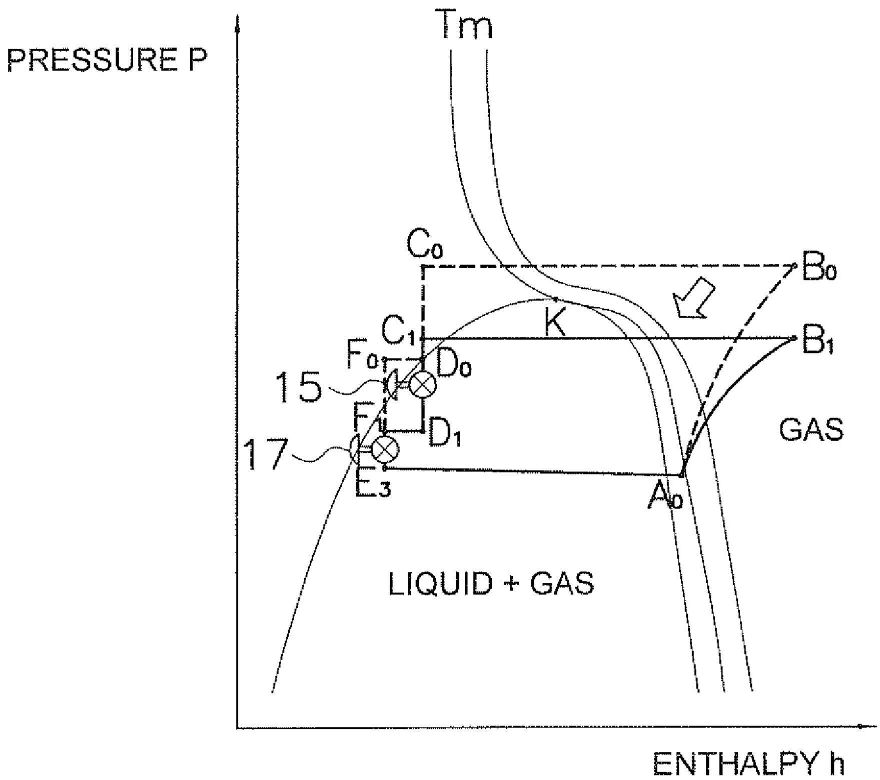
PRESSURE P
Tm
C0
B0
K
C1
B1
F0
D0
15
F1
D1
GAS
17
E3
A0
LIQUID + GAS
ENTHALPY h

FIG. 7

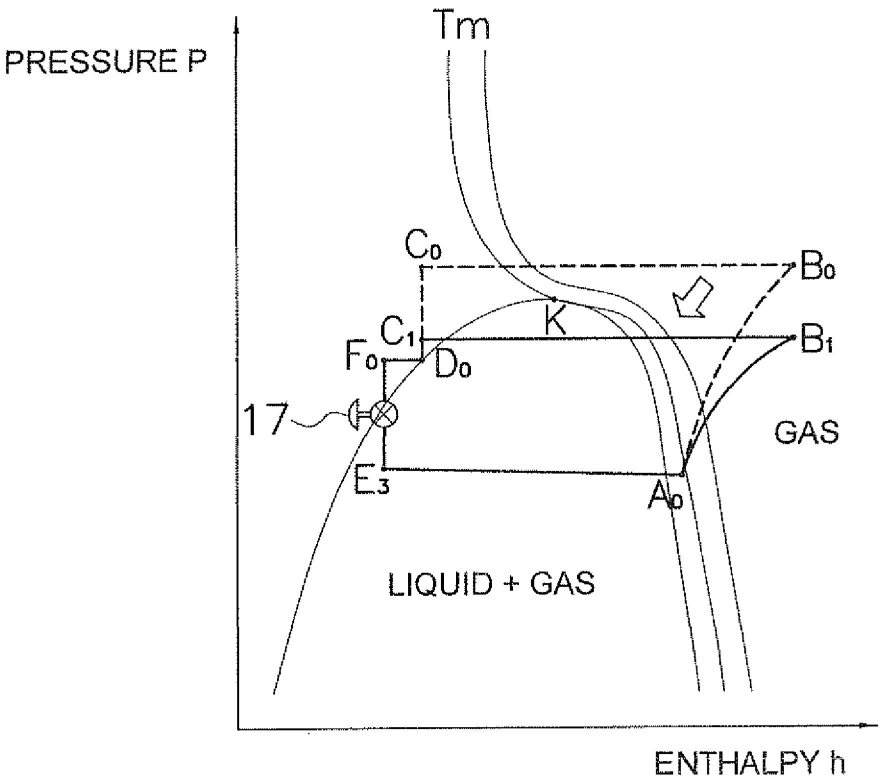
PRESSURE P
Tm
C0
B0
K
C1
B1
F0
D0
17
GAS
E3
A0
LIQUID + GAS
ENTHALPY h

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 10130470 A **[0003]**
- WO 03019085 A1 **[0004]**