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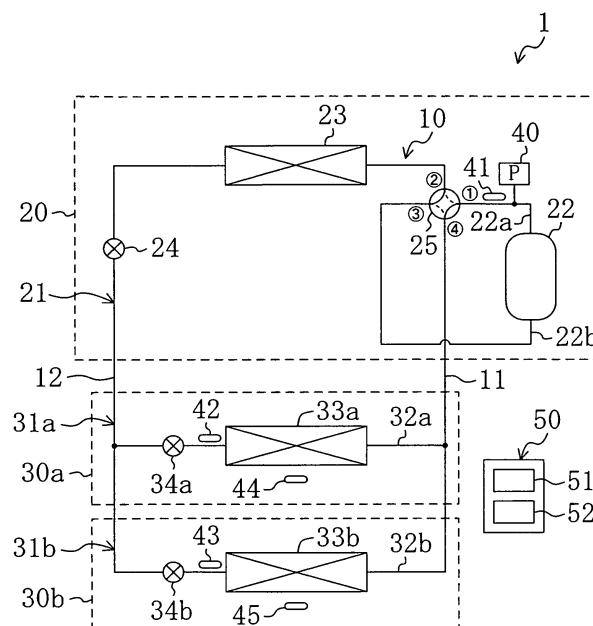
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(54) **REFRIGERATING APPARATUS**

(57) A refrigerant circuit (10) operates in a refrigeration cycle in which the pressure of refrigerant discharged from a compressor (22) is at or above the critical pressure. In performing an operation in which a first indoor

heat exchanger (33a) performs a heating operation and, concurrently, a second indoor heat exchanger is made inactive, an indoor expansion valve (34b) associated with the inactive indoor heat exchanger (33b) is fully closed.

FIG. 1



Description

Technical Field

[0001] This invention relates to refrigeration systems in which each of a plurality of utilization side heat exchangers can individually perform a heating operation and particularly relates to measures against refrigerant liquefaction in inactive ones of the utilization side heat exchangers.

Background Art

[0002] Refrigeration systems operating in a refrigeration cycle by circulating refrigerant therethrough are widely applied, such as to air conditioning systems. Such air conditioning systems include a so-called multi-type air conditioning system in which a plurality of indoor units are connected in parallel to an outdoor unit.

[0003] For example, an air conditioning system disclosed in Patent Document 1 includes a single outdoor unit having a compressor and an outdoor heat exchanger (heat-source side heat exchanger) and two indoor units each having an indoor heat exchanger (utilization side heat exchanger). Two branch pipes, each connected to an associated one of the two indoor heat exchangers, are provided with their respective electric motor-operated valves in association with the respective indoor heat exchangers.

[0004] In the air conditioning system, each of the indoor units can individually perform a heating operation by controlling the opening of the associated electric motor-operated valve. Specifically, for example, when the two indoor units concurrently perform a heating operation, both the electric motor-operated valves are opened at a predetermined opening to positively feed refrigerant into both the indoor heat exchangers. As a result, heat is released from refrigerant flowing through both the indoor heat exchangers to room air, thereby heating respective room spaces. On the other hand, for example, when only one of the indoor units performs a heating operation, the electric motor-operated valve associated with the active indoor unit is opened but the electric motor-operated valve associated with the deactivated indoor unit is closed. As a result, refrigerant is fed only into the indoor heat exchanger in the active indoor unit and the refrigerant in this indoor heat exchanger releases heat to room air.

Patent Document 1: Published Japanese Patent Application No. H08-159590

Disclosure of the Invention

Problems to Be Solved by the Invention

[0005] When only one of the two indoor units is continuously operated as described above, there may occur a phenomenon in which refrigerant in the inactive indoor

heat exchanger condenses and accumulates therein, or a so-called refrigerant liquefaction. If refrigerant is thus gradually liquefied in the inactive indoor heat exchanger, the indoor heat exchanger being active (in heating operation) becomes deficient in the amount of refrigerant flowing therethrough, which deteriorates the heating capacity of the active indoor unit.

[0006] The present invention has been made in view of the foregoing point and, therefore, an object thereof is to prevent refrigerant liquefaction in the inactive utilization side heat exchanger.

Means to Solve the Problems

[0007] A first aspect of the invention is directed to a refrigeration system including a refrigerant circuit (10) formed so that a plurality of utilization side circuits (31a, 31b) including their respective utilization side heat exchangers (33a, 33b) and electric motor-operated valves (34a, 34b) associated with the respective utilization side heat exchangers (33a, 33b) are connected in parallel to a heat-source side circuit (21) including a compressor (22) and a heat-source side heat exchanger (23), each of the utilization side heat exchangers (33a, 33b) being capable of individually performing a heating operation to release heat from refrigerant in the utilization side heat exchanger (33a, 33b). Furthermore, in the refrigeration system, the refrigerant circuit (10) is configured to operate in a refrigeration cycle in which the pressure of refrigerant discharged from the compressor (22) is at or above the critical pressure.

[0008] The refrigeration system according to the first aspect of the invention can perform an operation in which all of the utilization side heat exchangers (33a, 33b) perform the heating operation (hereinafter, referred to as a full operation) and an operation in which one or some of the utilization side heat exchangers (33b) halt the heating operation and, concurrently, the rest of the utilization side heat exchangers (33a) perform the heating operation (hereinafter, referred to as a partial operation).

[0009] Specifically, the full operation can be achieved by opening each of the electric motor-operated valves (34a, 34b) associated with the utilization side heat exchangers (33a, 33b) at a predetermined opening. Thus, in the full operation, refrigerant discharged from the compressor (22) flows through each of the utilization side heat exchangers (33a, 33b). Consequently, heat is released from refrigerant flowing through each of the utilization side heat exchangers (33a, 33b), whereby each utilization side heat exchanger (33a, 33b) performs a heating operation. As a result, each utilization side heat exchanger (33a, 33b) heats a room space, for example.

[0010] On the other hand, in the case of halting the heating operation of one or more utilization side heat exchangers (33b) out of the utilization side heat exchangers (33a, 33b), the electric motor-operated valve (34b) associated with each utilization side heat exchanger (33b) to be inactive is set to a minute opening or fully closed

and, concurrently, the electric motor-operated valve (34a) associated with each utilization side heat exchanger (33a) to perform a heating operation is opened at a predetermined opening. As a result, refrigerant flows substantially only through the utilization side heat exchangers (33a) in heating operation and each inactive utilization side heat exchanger (33b) does not perform a heating operation.

[0011] As the refrigeration system performs such a partial operation, owing to reduction in the opening of the electric motor-operated valve (34b) in each deactivated unit, refrigerant gradually accumulates in the inactive utilization side heat exchanger (33b). In this case, if the refrigeration system operated in a refrigeration cycle using refrigerant made, such as of HFC, to bring the discharge pressure of the compressor to a subcritical pressure and the deactivation of the utilization side heat exchanger (33b) dropped the ambient temperature thereof, refrigerant in the inactive utilization side heat exchanger (33b) would gradually condense. As a result, refrigerant would liquefy in the inactive utilization side heat exchanger (33b), which causes a problem that the utilization side heat exchangers (33a) in heating operation fall short of the amount of refrigerant flowing therethrough.

[0012] In this aspect of the invention, to prevent such refrigerant liquefaction in each inactive utilization side heat exchanger (33b), the pressure of refrigerant discharged from the compressor (22) is set at or above the critical pressure. In other words, the refrigerant circuit (10) of the refrigeration system according to this aspect of the invention operates in a refrigeration cycle in which refrigerant reaches or exceeds its critical pressure (a so-called supercritical cycle). As a result, in the partial operation, refrigerant in a critical state accumulates in the inactive utilization side heat exchanger (33b) and, therefore, the refrigerant does not condense in the utilization side heat exchanger (33b). Thus, as compared with the conventional refrigerant circuit operating in a refrigeration cycle using refrigerant made, such as of HFC, refrigerant does not change its phase in each inactive utilization side heat exchanger (33b) in this aspect of the invention, whereby the rate of refrigerant liquefaction in the inactive utilization side heat exchanger (33b) becomes low.

[0013] A second aspect of the invention is the refrigeration system according to the first aspect of the invention and further including a control means (51) that, in performing an operation in which at least one said utilization side heat exchanger (33a) in heating operation and at least one said inactive utilization side heat exchanger (33b) coexist, fully closes the electric motor-operated valve (34b) associated with the at least one inactive utilization side heat exchanger (33b).

[0014] In the second aspect of the invention, in performing the above partial operation, the control means (51) fully closes the electric motor-operated valve (34b) associated with each inactive utilization side heat exchanger (33b). As a result, refrigerant gradually accu-

mulates in each inactive utilization side heat exchanger (33b). However, in this aspect of the invention, the amount of refrigerant liquefied in the inactive utilization side heat exchanger (33b) is significantly reduced since the refrigeration system operates in a supercritical cycle as described above.

[0015] Furthermore, since the electric motor-operated valve (34b) is thus fully closed, refrigerant flows only through the utilization side heat exchangers (33a) in heating operation. Therefore, it can be avoided that refrigerant flows through each inactive utilization side heat exchanger (33b) to cause wasteful heat release from the utilization side heat exchanger (33b).

[0016] A third aspect of the invention is the refrigeration system according to the second aspect of the invention, wherein when a first specified time t1 has passed since full closure of the electric motor-operated valve (34b) associated with the at least one inactive utilization side heat exchanger (33b), the control means (51) temporarily opens the electric motor-operated valve (34b) for a second specified time t2.

[0017] In the third aspect of the invention, when in performing the partial operation the first specified time t1 has passed since full closure of the electric motor-operated valve (34b) associated with each inactive utilization side heat exchanger (33b), the control means (51) opens the electric motor-operated valve (34b) to a predetermined opening (preferably, a relatively minute opening). The reason for this is that when the partial operation is continued for a long period of time, refrigerant might gradually liquefy in each inactive utilization side heat exchanger (33b) even when the refrigeration system operates in a supercritical cycle as described above. For this reason, in the partial operation in this aspect of the invention, when the first specified time t1 has passed, the electric motor-operated valve (34b) is forcibly opened so that refrigerant flows through the inactive utilization side heat exchanger (33b) only for the second specified time t2. Thus, refrigerant in the inactive utilization side heat exchanger (33b) flows for the second specified time t2, whereby the temperature of the utilization side heat exchanger (33b) and its ambient temperature increase to eliminate refrigerant liquefaction. Then, when the second specified time t2 has passed, the electric motor-operated valve (34b) is fully closed again.

[0018] A fourth aspect of the invention is the refrigeration system according to the third aspect of the invention, wherein each of the utilization side heat exchangers (33a, 33b) is placed in a room and configured to release heat from refrigerant to a room air, room temperature sensors (44, 45) for detecting the temperatures of rooms associated with the respective utilization side heat exchangers (33a, 33b) are provided around the respective utilization side heat exchangers (33a, 33b), and the refrigeration system further includes a correction means (52) that corrects one or both of the first specified time t1 and the second specified time t2 based on the temperature detected by the room temperature sensor (45)

associated with the at least one inactive utilization side heat exchanger (33b).

[0019] In the fourth aspect of the invention, the correction means (52) corrects one or both of the first specified time t1 and the second specified time t2 based on the room temperature detected by the room temperature sensor (45) around each inactive utilization side heat exchanger (33b).

[0020] More specifically, for example, when the room temperature around an inactive utilization side heat exchanger (33b) is high, refrigerant is less likely to liquefy in the inactive utilization side heat exchanger (33b). Therefore, in such a case, the period of time during which the associated electric motor-operated valve (34b) is fully closed can be extended by making a correction to increase the first specified time t1 or a correction to decrease the second specified time t2. As a result, it can be avoided that refrigerant wastefully releases heat in the inactive utilization side heat exchanger (33b).

[0021] On the other hand, for example, when the room temperature around an inactive utilization side heat exchanger (33b) is low, refrigerant is likely to liquefy in the inactive utilization side heat exchanger (33b). Therefore, in such a case, refrigerant liquefaction in the utilization side heat exchanger (33b) can be avoided in advance by making a correction to decrease the first specified time t1 or a correction to increase the second specified time t2.

[0022] In a fifth aspect of the invention, the refrigeration system further includes refrigerant density detecting devices (40, 41, 42, 43) for detecting the refrigerant densities in the associated utilization side heat exchangers (33a, 33b), wherein when the refrigerant density detected by at least one said refrigerant density detecting device (40, 41, 43) associated with the at least one inactive utilization side heat exchanger (33b) exceeds a specified refrigerant density after full closure of the electric motor-operated valve (34b) associated with the at least one inactive utilization side heat exchanger (33b), the control means (51) temporarily opens the electric motor-operated valve (34b).

[0023] In the fifth aspect of the invention, in performing the partial operation, the refrigerant density in each inactive utilization side heat exchanger (33b) is detected by the associated refrigerant density detecting device (40, 41, 43) after full closure of the electric motor-operated valve (34b) associated with the inactive utilization side heat exchanger (33b). In other words, the refrigerant detecting means (40, 41, 43) indirectly detects the amount of refrigerant accumulated in the inactive utilization side heat exchanger (33b) based on the refrigerant density. Then, when the detected refrigerant density exceeds a specified refrigerant density, the control means (51) considers a large amount of refrigerant to be accumulated in the inactive utilization side heat exchanger (33b) and temporarily opens the electric motor-operated valve (34b). As a result, refrigerant liquefaction in the inactive utilization side heat exchanger (33b) can be avoided in advance.

[0024] A sixth aspect of the invention is the refrigeration system according to any one of the first to fifth aspects of the invention, wherein the refrigerant circuit (10) is filled with carbon dioxide as refrigerant.

5 [0025] In the sixth aspect of the invention, the refrigerant circuit (10) operates in a supercritical cycle using carbon dioxide.

[0026] A seventh aspect of the invention is the refrigeration system according to any one of the second to fifth aspects of the invention and further including supply openings through which air having passed through the associated utilization side heat exchangers (33a, 33b) is let out and opening/closing mechanisms for opening and closing the associated supply openings, wherein each of the opening/closing mechanisms is configured to open the supply opening of the associated utilization side heat exchanger (33b) when in heating operation and close the supply opening of the associated utilization side heat exchanger (33a) when inactive.

20 [0027] The refrigeration system according to the seventh aspect of the invention is provided with a plurality of supply openings associated with their respective utilization side heat exchangers (33a, 33b). Furthermore, each supply opening is provided with an opening/closing mechanism for opening and closing the supply opening. In this case, in the full operation, the opening/closing mechanisms for all the supply openings are put into an open position, whereby air heated by the utilization side heat exchangers (33a, 33b) is supplied into rooms or the like through the supply openings. On the other hand, in the partial operation, the opening/closing mechanism for the supply opening in each utilization side heat exchanger (33a) in heating operation is put into an open position but the opening/closing mechanism for the supply opening in each inactive utilization side heat exchanger (33b) is put into a closed position. As a result, in each inactive utilization side heat exchanger (33b), it can be prevented that heat of refrigerant therein escapes through the supply opening to another space, such as a room. Therefore, the drop in the ambient temperature of each inactive utilization side heat exchanger (33b) can be restrained, whereby refrigerant liquefaction in this utilization side heat exchanger (33b) can be effectively avoided.

45 *Effects of the Invention*

[0028] In the present invention, the refrigeration system, in which each of a plurality of utilization side heat exchangers (33a, 33b) can individually perform a heating operation, operates in a supercritical cycle in which the pressure of refrigerant discharged from the compressor (22) is at or above the critical pressure. Thus, even when in the above-stated partial operation the electric motor-operated valve (34b) in each deactivated unit is opened at a minute opening or fully closed, refrigerant is less likely to liquefy in the inactive utilization side heat exchanger (33a, 33b). Therefore, according to the present invention, it can be eliminated that each utilization side

heat exchanger (33a) in heating operation falls short of the amount of refrigerant flowing therethrough, thereby providing a sufficient heating capacity of the utilization side heat exchanger (33a) in heating operation.

[0029] Particularly in the second aspect of the invention, the electric motor-operated valve (34b) in each deactivated unit is fully closed in performing the partial operation. Thus, according to the second aspect of the invention, all the refrigerant is fed to the utilization side heat exchangers (33a) in heating operation, whereby it can be avoided that each inactive utilization side heat exchanger (33b) causes wasteful heat release. Therefore, according to this aspect of the invention, the heating capacity of each utilization side heat exchanger (33a) in heating operation can be enhanced and, in turn, the COP (coefficient of performance) of the refrigeration system can be increased.

[0030] Furthermore, in the third aspect of the invention, the electric motor-operated valve (34b) once fully closed in performing the partial operation is opened only for the second specified time t2 after the passage of the first specified time t1. Therefore, according to the third aspect of the invention, when the partial operation is continued for a long period of time, refrigerant liquefaction in each inactive utilization side heat exchanger (33b) can be certainly eliminated, which ensures the reliability of the refrigeration system.

[0031] Particularly, in the fourth aspect of the invention, during the partial operation, the first specified time t1 and the second specified time t2 are corrected based on the room temperature around each inactive utilization side heat exchanger (33b). Therefore, according to the fourth aspect of the invention, it can be certainly avoided that the full-closure time of the electric motor-operated valve (34b) becomes longer than necessary to cause refrigerant liquefaction in the associated inactive utilization side heat exchanger (33b). Furthermore, according to the fourth aspect of the invention, it can be certainly avoided that the open time of the electric motor-operated valve (34b) becomes longer than necessary to cause wasteful heat release in the associated inactive utilization side heat exchanger (33b).

[0032] Furthermore, in the fifth aspect of the invention, the refrigerant density in each inactive utilization side heat exchanger (33b) is detected during the partial operation and when the refrigerant density exceeds the specified refrigerant density, the fully closed electric motor-operated valve (34b) is temporarily opened. In other words, in the fifth aspect of the invention, the amount of refrigerant accumulated in each inactive utilization side heat exchanger (33b) is indirectly determined and when the amount of refrigerant becomes large, the electric motor-operated valve (34b) is opened. Therefore, refrigerant liquefaction in each inactive utilization side heat exchanger (33b) can be certainly avoided.

[0033] Furthermore, according to the sixth aspect of the invention, by using carbon dioxide as refrigerant, the refrigeration system can operate in a supercritical cycle

with natural refrigerant of relatively low critical temperature.

[0034] Furthermore, in the seventh aspect of the invention, the supply opening in each inactive utilization side heat exchanger (33b) is closed by the opening/closing mechanism during the partial operation. Therefore, the drop in the ambient temperature of the utilization side heat exchanger (33b) can be restrained, whereby refrigerant liquefaction in the utilization side heat exchanger (33b) can be further effectively avoided.

Brief Description of Drawings

[0035]

[Fig. 1] Figure 1 is a piping diagram of a refrigerant circuit of an air conditioning system according to an embodiment.

[Fig. 2] Figure 2 is a piping diagram showing the refrigerant flow of the refrigerant circuit during a full heating operation.

[Fig. 3] Figure 3 is a piping diagram showing the refrigerant flow of the refrigerant circuit during a partial heating operation.

[Fig. 4] Figure 4 is a P-H diagram (Mollier diagram) of a supercritical cycle according to the above embodiment.

[Fig. 5] Figure 5 is a P-H diagram (Mollier diagram) of a refrigeration cycle according to a conventional example.

[Fig. 6] Figure 6 is a piping diagram showing the refrigerant flow of a refrigerant circuit during a partial heating operation of an air conditioning system according to a modification.

[Fig. 7] Figure 7 is a graph showing behaviors of changes of refrigerant density and refrigerant temperature within the range from the entrance to the exit of an inactive indoor heat exchanger in the above embodiment.

[Fig. 8] Figure 8 is a graph showing behaviors of changes of refrigerant density and refrigerant temperature within the range from the entrance to the exit of an inactive indoor heat exchanger in a conventional example.

List of Reference Characters

[0036]

- | | |
|-----|---|
| 1 | air conditioning system (refrigeration system) |
| 10 | refrigerant circuit |
| 21 | outdoor circuit (heat-source side circuit) |
| 22 | compressor |
| 23 | outdoor heat exchanger (heat-source side heat exchanger) |
| 33a | first indoor heat exchanger (utilization side heat exchanger) |
| 33b | second indoor heat exchanger (utilization side |

- heat exchanger)
- 34a** first indoor expansion valve (electric motor-operated valve)
- 34b** second indoor expansion valve (electric motor-operated valve)
- 44** first room temperature sensor (room temperature sensor)
- 45** second room temperature sensor (room temperature sensor)
- 51** control means
- 52** correction means

Best Mode for Carrying Out the Invention

[0037] Embodiments of the present invention will be described below in detail with reference to the drawings.

[0038] A refrigeration system according to an embodiment constitutes a so-called multi-type air conditioning system (1) that can perform heating and cooling of a room. As shown in Figure 1, the air conditioning system (1) includes a single outdoor unit (20) placed outdoors and first and second indoor units (30a, 30b) placed in different rooms.

[0039] The outdoor unit (20) is provided with an outdoor circuit (21) constituting a heat-source side circuit. The first indoor unit (30a) and the second indoor unit (30b) are provided with a first indoor circuit (31a) constituting a utilization side circuit and a second indoor circuit (31b) constituting another utilization side circuit, respectively.

[0040] The indoor circuits (31a, 31b) are connected in parallel via a first connection pipe (11) and a second connection pipe (12) to the outdoor circuit (21). As a result, in this air conditioning system (1), a refrigerant circuit (10) operating in a refrigeration cycle by circulating refrigerant therethrough is constituted. The refrigerant circuit (10) is filled with carbon dioxide as refrigerant.

[0041] The outdoor circuit (21) is provided with a compressor (22), an outdoor heat exchanger (23), an outdoor expansion valve (24) and a four-way selector valve (25). The compressor (22) is a fully-enclosed, high-pressure domed scroll compressor. The compressor (22) is supplied through an inverter with electric power. In other words, the compressor (22) can be changed in capacity by changing the output frequency of the inverter and thereby changing the rotational speed of a motor for the compressor. The outdoor heat exchanger (23) is a cross-fin-and-tube heat exchanger and constitutes a heat-source side heat exchanger. In the outdoor heat exchanger (23), heat is exchanged between refrigerant and outdoor air. The outdoor expansion valve (24) is composed of an electronic expansion valve controllable in opening.

[0042] The four-way selector valve (25) has first to fourth ports. The four-way selector valve (25) is connected at the first port to a discharge pipe (22a) of the compressor (22), connected at the second port to the outdoor heat exchanger (23), connected at the third port to a suc-

tion pipe (22b) of the compressor (22) and connected at the fourth port to the first connection pipe (11). The four-way selector valve (25) is configured to be switchable between a position (the position shown in the solid lines in Figure 1) in which the first and fourth ports are communicated with each other and the second and third ports are communicated with each other and a position (the position shown in the broken lines in Figure 1) in which the first and second ports are communicated with each other and the third and fourth ports are communicated with each other.

[0043] The first indoor circuit (31a) is provided with a first branch pipe (32a) connected at one end to the first connection pipe (11) and connected at the other end to the second connection pipe (12). The first branch pipe (32a) is provided with a first indoor heat exchanger (33a) and a first indoor expansion valve (34a). The second indoor circuit (31b) is provided with a second branch pipe (32b) connected at one end to the first connection pipe (11) and connected at the other end to the second connection pipe (12). The second branch pipe (32b) is provided with a second indoor heat exchanger (33b) and a second indoor expansion valve (34b).

[0044] Each of the indoor heat exchangers (33a, 33b) is a cross-fin-and-tube heat exchanger and constitutes a utilization side heat exchanger. In each of the indoor heat exchangers (33a, 33b), heat is exchanged between refrigerant and room air.

[0045] The first indoor expansion valve (34a) and the second indoor expansion valve (34b) are electric motor-operated valves and each constitutes an electronic expansion valve controllable in opening. The first indoor expansion valve (34a) is provided in a part of the first branch pipe (32a) close to the second connection pipe (12). The second indoor expansion valve (34b) is provided in a part of the second branch pipe (32b) close to the second connection pipe (12). The first indoor expansion valve (34a) can control the flow rate of refrigerant flowing through the first indoor heat exchanger (33a), while the second indoor expansion valve (34b) can control the flow rate of refrigerant flowing through the second indoor heat exchanger (33b).

[0046] The refrigerant circuit (10) is further provided with a high-side pressure sensor (40), a high-pressure temperature sensor (41), a first refrigerant temperature sensor (42) and a second refrigerant temperature sensor (43). The high-side pressure sensor (40) detects the pressure of refrigerant discharged from the compressor (22). The high-pressure temperature sensor (41) detects the temperature of refrigerant discharged from the compressor (22). The first refrigerant temperature sensor (42) is disposed at the exit of the first indoor heat exchanger (33a) to detect the temperature of refrigerant just after flowing out of the first indoor heat exchanger (33a). The second refrigerant temperature sensor (43) is disposed at the exit of the second indoor heat exchanger (33b) to detect the temperature of refrigerant just after flowing out of the second indoor heat exchanger (33b).

[0047] The first indoor unit (30a) is provided also with a first room temperature sensor (44) in the vicinity of the first indoor heat exchanger (33a). The first room temperature sensor (44) detects the air temperature around the first indoor heat exchanger (33a). The second indoor unit (30b) is provided also with a second room temperature sensor (45) in the vicinity of the second indoor heat exchanger (33b). The second room temperature sensor (45) detects the air temperature around the second indoor heat exchanger (33b).

[0048] The refrigerant circuit (10) of the air conditioning system (1) according to this embodiment operates in a refrigeration cycle (supercritical cycle) in which the pressure of refrigerant discharged from the compressor (22) is at or above the critical pressure. Furthermore, in the air conditioning system (1), each of the first indoor unit (30a) and the second indoor unit (30b) is individually operable. Specifically, the air conditioning system (1) can perform an operation in which the first indoor unit (30a) heats a room and the second indoor unit (30b) is deactivated (hereinafter, referred to as a partial heating operation) or an operation in which both the first indoor unit (30a) and the second indoor unit (30b) heat different rooms (hereinafter, referred to as full heating operation).

[0049] The air conditioning system (1) is provided also with a controller (50) for controlling the openings of the indoor expansion valves (34a, 34b). The controller (50) includes a control means (51) and a correction means (52). The details of control of the controller (50) on the openings of the indoor expansion valves (34a, 34b) will be described later.

- Operational Behavior -

[0050] Next, a description is given of the operational behavior of the air conditioning system (1) according to this embodiment. The air conditioning system (1) can perform an operation in which each indoor unit (30a, 30b) heats a room and an operation in which each indoor unit (30a, 30b) cools a room. A description is given below of the heating operation of the air conditioning system (1). In the heating operation, the four-way selector valve (25) is selected to the position shown in Figures 2 and 3 so that the above-stated full heating operation and partial heating operation are selectively carried out.

<Full Heating Operation>

[0051] In the full heating operation, the first indoor expansion valve (34a) and the second indoor expansion valve (34b) are opened at a predetermined opening. As shown in Figure 2, refrigerant condensed to the critical pressure or higher by the compressor (22) flows through the four-way selector valve (25) and the first connection pipe (11) and is then distributed to the first branch pipe (32a) and the second branch pipe (32b).

[0052] The refrigerant having flowed into the first branch pipe (32a) flows through the first indoor heat ex-

changer (33a). In the first indoor heat exchanger (33a), the refrigerant releases heat to room air. In other words, the first indoor heat exchanger (33a) performs a heating operation to heat room air, thereby heating the room in which the first indoor unit (30a) is installed. The refrigerant having flowed out of the first indoor heat exchanger (33a) passes through the first indoor expansion valve (34a) and then flows into the second connection pipe (12).

[0053] On the other hand, the refrigerant having flowed into the second branch pipe (32b) flows through the second indoor heat exchanger (33b). In the second indoor heat exchanger (33b), the refrigerant releases heat to room air. In other words, the second indoor heat exchanger (33b) performs a heating operation to heat room air, thereby heating the room in which the second indoor unit (30b) is installed. The refrigerant having flowed out of the second indoor heat exchanger (33b) passes through the second indoor expansion valve (34b) and then flows into the second connection pipe (12).

[0054] The refrigerant combined in the second connection pipe (12) is reduced in pressure when passing through the outdoor expansion valve (24) and then flows through the outdoor heat exchanger (23). In the outdoor heat exchanger (23), the refrigerant takes heat from outdoor air to evaporate. The refrigerant having flowed out of the outdoor heat exchanger (23) passes through the four-way selector valve (25) and is then sucked into the compressor (22). In the compressor (22), the refrigerant is compressed to the critical pressure or higher.

<Partial Heating Operation>

[0055] In the partial heating operation, the air conditioning system (1) performs an operation in which the first indoor heat exchanger (33a) performs the heating operation and, concurrently, the second indoor heat exchanger (33b) halts the heating operation or an operation in which the second indoor heat exchanger (33b) performs the heating operation and, concurrently, the first indoor heat exchanger (33a) halts the heating operation. Here, a description is typically given of the operation in which only the first indoor heat exchanger (33a) performs the heating operation with reference to Figure 3.

[0056] In the partial heating operation, the control means (51) of the controller (50) opens the first indoor expansion valve (34a) at a predetermined opening and sets the second indoor expansion valve (34b) at a fully closed position. When the first indoor expansion valve (34a) is opened, the first indoor heat exchanger (33a) performs the heating operation as described previously. On the other hand, when the second indoor expansion valve (34b) is fully closed, refrigerant does not pass through the second indoor expansion valve (34b). Therefore, refrigerant does not flow through the second indoor heat exchanger (33b), whereby the second indoor heat exchanger (33b) is made inactive.

[0057] When the second indoor heat exchanger (33b)

is thus made inactive, refrigerant gradually accumulates in the second indoor heat exchanger (33b). However, also in the partial heating operation, the air conditioning system (1) of this embodiment, operates in a supercritical cycle in which the pressure of refrigerant discharged from the compressor (22) is at or above the critical pressure. Thus, even if the ambient temperature of the second indoor heat exchanger (33b) drops owing to deactivation of the second indoor heat exchanger (33b), refrigerant in the second indoor heat exchanger (33b) does not condense. Therefore, the rate of refrigerant liquefaction in the second indoor heat exchanger (33b) is significantly reduced as compared with that in the case where an air conditioning system operates in a subcritical refrigeration cycle, for example, using HFC.

[0058] This point is described more closely with reference to Figures 4 and 5. Figure 4 shows a P-H diagram of a supercritical cycle using carbon dioxide in this embodiment, and Figure 5 shows a P-H diagram of a conventional subcritical refrigeration cycle using HFC.

[0059] In the conventional refrigeration cycle shown in Figure 5, the pressure of refrigerant discharged from the compressor is below the critical pressure. Specifically, for example, refrigerant after compressed in the refrigeration cycle has a pressure of 2.7 MPa, a temperature of 80°C and a refrigerant density ρ_1 of 85 kg/m³. When the refrigerant condenses in the indoor heat exchanger, the refrigerant after condensation has a pressure of 2.7 MPa, a temperature of 37°C and a refrigerant density ρ_2 of 996 kg/m³. In other words, in the conventional refrigeration cycle, the density ratio (ρ_2/ρ_1) between refrigerant density ρ_2 at the exit of the indoor heat exchanger and refrigerant density ρ_1 at the entrance thereof is 11.72.

[0060] On the other hand, in this embodiment shown in Figure 4, the pressure of refrigerant discharged from the compressor is above the critical pressure. Specifically, for example, refrigerant after compressed in this cycle has a pressure of 10 MPa, a temperature of 80°C and a refrigerant density ρ_1 of 221 kg/m³. When the refrigerant releases heat in the indoor heat exchanger, the refrigerant after heat release has a pressure of 10 MPa, a temperature of 35°C and a refrigerant density ρ_2 of 713 kg/m³. In other words, in a supercritical cycle according to this embodiment, the density ratio (ρ_2/ρ_1) between refrigerant density ρ_2 at the exit of the indoor heat exchanger and refrigerant density ρ_1 at the entrance thereof is 3.23.

[0061] As can be seen from the above, comparison of the density ratio (ρ_2/ρ_1) between before and after the indoor heat exchanger in the conventional cycle with that in the refrigeration cycle according to this embodiment shows that the density ratio in the conventional cycle is three or more times greater than that in the refrigeration cycle according to this embodiment. In other words, in the conventional refrigeration cycle, when refrigerant condenses in the inactive indoor heat exchanger, it has a high density to reduce its volume and is therefore rapidly fed into the inactive indoor heat exchanger. Thus, in

the conventional refrigeration cycle, the rate of refrigerant liquefaction in the inactive indoor heat exchanger is relatively high.

[0062] In contrast, in this embodiment, even when refrigerant releases heat in the inactive indoor heat exchanger, it has a relatively low density and, therefore, its volume is not so reduced. Thus, refrigerant is not so fed into the indoor heat exchanger, whereby the rate of refrigerant liquefaction in the inactive indoor heat exchanger is relatively low.

[0063] However, when such a partial heating operation is continued for a long period of time, the amount of refrigerant liquefied in the second indoor heat exchanger (33b) gradually increases. To cope with this, when a first specified time t1 has passed since the start of the partial heating operation with full closure of the second indoor expansion valve (34b), the control means (51) in this embodiment opens the second indoor expansion valve (34b) at a minute opening only for a second specified time t2. Thus, a minute flow rate of refrigerant flows through the second indoor heat exchanger (33b) to increase the temperature of the second indoor heat exchanger (33b) and the ambient temperature thereof. As a result, refrigerant liquefaction in the second indoor heat exchanger (33b) can be eliminated. Thereafter, when the second specified time t2 has passed, the control means (51) fully closes the second indoor expansion valve (34b) again.

[0064] Furthermore, the amount of refrigerant liquefied in the second indoor heat exchanger (33b) since the start of the partial heating operation with full closure of the second indoor expansion valve (34b) depends on the ambient temperature of the second indoor heat exchanger (33b). In other words, if the temperature of a room where the second indoor heat exchanger (33b) is installed is relatively low, the rate of refrigerant liquefaction in the second indoor heat exchanger (33b) becomes high. On the other hand, if the temperature of the room is relatively high, the rate of refrigerant liquefaction becomes low. To cope with this, the correction means (52) of the controller (50) in this embodiment controls the room temperature sensor (45) to detect the room temperature around the inactive indoor heat exchanger (33b) and corrects the above-stated first specified time t1 and second specified time t2 based on the detected room temperature.

[0065] Specifically, if the room temperature detected by the second room temperature sensor (45) at the start of the partial heating operation is relatively low, the correction means (52) decreases the first specified time t1. Furthermore, if the room temperature detected by the second room temperature sensor (45) after the passage of the first specified time t1 is relatively low, the correction means (52) increases the second specified time t2. As results of these corrections, the period of time during which the second indoor expansion valve (34b) is fully closed in the partial heating operation becomes short, whereby refrigerant liquefaction in the second indoor

heat exchanger (33b) can be eliminated in advance. Either one of such corrections of the first specified time t1 and the second specified time t2 may be carried out or both of them may be carried out.

[0066] On the other hand, if the room temperature detected by the second room temperature sensor (45) at the start of the partial heating operation is relatively high, the correction means (52) increases the first specified time t1. Furthermore, if the room temperature detected by the second room temperature sensor (45) after the passage of the first specified time t1 is relatively high, the correction means (52) decreases the second specified time t2. As results of these corrections, the period of time during which the second indoor expansion valve (34b) is open in the partial heating operation becomes short, whereby the inactive second indoor heat exchanger (33b) does not cause wasteful heat release.

- Effects of Embodiment -

[0067] In this embodiment, the air conditioning system (1), in which each of a plurality of indoor heat exchangers (33a, 33b) can individually perform a heating operation, operates in a supercritical cycle in which the pressure of refrigerant discharged from the compressor (22) is at or above the critical pressure. Thus, even when the inactive indoor expansion valve (34b) is fully closed in the partial heating operation, refrigerant does not condense in the inactive indoor heat exchanger (33b). Therefore, according to this embodiment, the rate of refrigerant liquefaction in the inactive indoor heat exchanger (33b) can be significantly reduced. As a result, deficiency in refrigerant in the indoor heat exchanger (33a) in heating operation can be avoided, thereby providing a sufficient heating capacity of the indoor heat exchanger (33a) in heating operation.

[0068] Furthermore, in this embodiment, the indoor expansion valve (34b) in the deactivated unit is fully closed in performing the partial heating operation. Therefore, according to this embodiment, the inactive indoor heat exchanger (33b) can be prevented from causing wasteful heat release. This increases the COP (coefficient of performance) of the air conditioning system (1).

[0069] Furthermore, in this embodiment, the indoor expansion valve (34b) once fully closed in performing the partial heating operation is opened only for the second specified time t2 after the passage of the first specified time t1. Therefore, according to this embodiment, also when the partial heating operation is continued for a long period of time, refrigerant liquefaction in the inactive indoor heat exchanger (33b) can be certainly eliminated, which certainly prevents shortage of amount of refrigerant in the indoor heat exchanger (33a) in heating operation.

[0070] Furthermore, in this embodiment, during the partial heating operation, the first specified time t1 and the second specified time t2 are corrected based on the room temperature around the inactive indoor heat ex-

changer (33b). Therefore, according to this embodiment, it can be avoided that the full-closure time of the indoor expansion valve (34b) becomes longer than necessary to cause refrigerant liquefaction in the inactive indoor heat exchanger (33b). Furthermore, according to this embodiment, it can be avoided that the open time of the indoor expansion valve (34b) becomes longer than necessary to cause wasteful heat release from refrigerant in the inactive indoor heat exchanger (33b). This further increases the COP of the air conditioning system (1).

- Modification of Control on Opening of Indoor Expansion Valve -

[0071] In the above embodiment, after the indoor expansion valve (33a, 33b) in the deactivated unit is fully closed in the partial heating operation, this indoor expansion valve (34b) is opened or closed based on the first specified time t1 and the second specified time t2. However, instead of such control on the opening of the indoor expansion valve (34b), the opening of the indoor expansion valve (34b) may be controlled in a manner as shown in Figure 6.

[0072] In a partial heating operation according to this modification, the refrigerant pressure detected by the high-side pressure sensor (40), the refrigerant temperature detected by the high-pressure temperature sensor (41), the refrigerant temperature detected by the first refrigerant temperature sensor (42) and the refrigerant temperature detected by the second refrigerant temperature sensor (43) are output to the controller (50). Then, the controller (50) determines, based on the detected values of these sensors (40, 41, 42, 43), the density of refrigerant flowing through the inactive indoor heat exchanger (33b) during the partial heating operation. In other words, each of the sensors (40, 41, 42, 43) constitutes a refrigerant density detecting device for detecting the refrigerant density in the inactive indoor heat exchanger (33b).

[0073] Specifically, for example, in performing the same partial heating operation as in the above embodiment, the control means (51) first brings the opening of the second indoor expansion valve (34b) into a fully closed position. When the partial heating operation is continued for a long period of time, refrigerant gradually liquefies in the second indoor heat exchanger (33b).

[0074] To cope with this, the control means (51) in this modification determines the refrigerant density in the inactive second indoor heat exchanger (33b) from the refrigerant pressure and the refrigerant temperature. Specifically, for example, in the case where the second indoor heat exchanger (33b) is made inactive, the controller (50) determines the refrigerant density in the second indoor heat exchanger (33b) based on the refrigerant pressure detected by the high-side pressure sensor (40), the refrigerant temperature detected by the high-pressure temperature sensor (41) and the refrigerant temperature detected by the second refrigerant temperature sensor (43).

in the deactivated unit. In fact, the refrigerant pressure detected by the high-side pressure sensor (40) is substantially equal to the refrigerant pressure in the second indoor heat exchanger (33b). Furthermore, the refrigerant temperature detected by the high-pressure temperature sensor (41) can be considered as the temperature of refrigerant flowing into the second indoor heat exchanger (33b) and the refrigerant temperature detected by the second refrigerant temperature sensor (43) can be the temperature of refrigerant having flowed out of the second indoor heat exchanger (33b). Therefore, from these temperatures of inflow refrigerant and outflow refrigerant, the average temperature of refrigerant in the indoor heat exchanger (33b) can be determined. Then, from this average refrigerant temperature and the above refrigerant pressure, the average refrigerant density of refrigerant in the second indoor heat exchanger (33b) can be determined.

[0075] The refrigerant density thus obtained gives an indication of the amount of refrigerant accumulated in the second indoor heat exchanger (33b). Then, when the refrigerant density obtained from the detected values of the sensors (40, 41, 43) exceeds a specified refrigerant density after the start of the partial heating operation with full closure of the second indoor expansion valve (34b), the control means (51) in this modification determines that a large amount of refrigerant is accumulated in the second indoor heat exchanger (33b), and temporarily opens the second indoor expansion valve (34b). As a result, refrigerant liquefaction in the second indoor heat exchanger (33b) can be certainly eliminated.

[0076] On the other hand, in a partial heating operation in which the first indoor heat exchanger (33a) is made inactive and the second indoor heat exchanger (33b) performs a heating operation, the refrigerant density in the first indoor heat exchanger (33a) is determined based on the detected values of the high-side pressure sensor (40), the high-pressure temperature sensor (41) and the first refrigerant temperature sensor (42) in the deactivated unit. In this case, when the refrigerant density exceeds the specified refrigerant density, the first indoor expansion valve (34a) is opened to eliminate refrigerant liquefaction in the first indoor heat exchanger (33a).

- Effects of Modification -

[0077] In this modification, the refrigerant density in the inactive indoor heat exchanger (33b) is detected during the partial heating operation and when the refrigerant density exceeds the specified refrigerant density, the fully closed indoor expansion valve (34b) is temporarily opened. In other words, in this modification, the amount of refrigerant accumulated in the inactive indoor heat exchanger (33b) is indirectly determined and when the amount of refrigerant becomes large, the indoor expansion valve (34b) is opened. Therefore, refrigerant liquefaction in the inactive indoor heat exchanger (33b) can be certainly avoided.

[0078] Furthermore, also in this modification, the refrigerant circuit (10) operates in a supercritical cycle during the partial heating operation, whereby the rate of refrigerant liquefaction in inactive one of the indoor heat exchangers (33a, 33b) can be significantly reduced.

[0079] Furthermore, when the refrigerant circuit (10) operates in a supercritical cycle in the above manner, the average refrigerant density in the inactive indoor heat exchanger (33b) can be more accurately obtained. Specifically, with reference to changes of refrigerant density (or refrigerant temperature) from the entrance to the exit of an inactive indoor heat exchanger in a conventional example (an air conditioning system in which the refrigerant circuit operates in a refrigeration cycle in which high-side pressure is a subcritical pressure) as for example shown in Figure 8, it can be noted that the behavior of the changes has poor linearity. The reason for this is that in the conventional example refrigerant in the inactive indoor heat exchanger condenses to change its phase. Therefore, in order to accurately obtain the amount of refrigerant accumulated in the indoor heat exchanger, it is necessary to detect the refrigerant density (or refrigerant temperature) at a plurality of points (for example, three or more points). This increases the number of temperature sensors.

[0080] In contrast, with reference to changes of refrigerant density (or refrigerant temperature) in the inactive indoor heat exchanger (33b) in this embodiment as shown in Figure 7, it can be noted that the behavior of the changes has a relatively high linearity. The reason for this is that in this embodiment refrigerant of critical pressure or higher pressure accumulates in the indoor heat exchanger (33b) and, therefore, the refrigerant in the indoor heat exchanger (33b) does not change its phase from the entrance to the exit. Therefore, according to this embodiment, by determining the refrigerant densities at the entrance and the exit in the manner shown in the above modification, the behavior of refrigerant densities from the entrance to the exit of the indoor heat exchanger (33b) can be accurately predicted based on a data table previously stored in the controller (50) (such as data on behavior of changes of refrigerant density or behavior of changes of refrigerant temperature). Then, by determining the timing of opening of the indoor expansion valve (34a, 34b) based on the refrigerant density thus obtained, refrigerant liquefaction in the inactive indoor heat exchanger (33b) can be more certainly avoided.

«Other Embodiments»

[0081] In the air conditioning system (1) according to the above embodiment, each of the supply openings, through which air having passed through the utilization side heat exchangers (33a, 33b) is supplied, may be provided with an opening/closing mechanism, such as a louver, that can open and close the supply opening. Furthermore, during the partial heating operation as de-

scribed above, only the supply opening associated with the inactive utilization side heat exchanger (33b) may be closed by the opening/closing mechanism. In this case, it can be prevented that heat of refrigerant accumulated in the inactive utilization side heat exchanger (33b) escapes through the supply opening to the room space. Therefore, the drop in the ambient temperature of the utilization side heat exchanger (33b) can be restrained, whereby refrigerant liquefaction in the utilization side heat exchanger (33b) can be further effectively avoided. If a sealing material, such as packing, is provided around the opening/closing mechanism, such as a louver, this is preferable because the sealing property of the supply opening when sealed is enhanced.

[0082] The above embodiments are merely preferred embodiments in nature and are not intended to limit the scope, applications and use of the invention.

Industrial Applicability

[0083] As can be seen from the above description, the present invention is useful as measures against refrigerant liquefaction in inactive ones of utilization side heat exchangers in a refrigeration system in which each of a plurality of utilization side heat exchangers can individually perform a heating operation.

Claims

1. A refrigeration system comprising a refrigerant circuit formed so that a plurality of utilization side circuits including their respective utilization side heat exchangers and electric motor-operated valves associated with the respective utilization side heat exchangers are connected in parallel to a heat-source side circuit including a compressor and a heat-source side heat exchanger, each of the utilization side heat exchangers being capable of individually performing a heating operation to release heat from refrigerant in the utilization side heat exchanger, wherein the refrigerant circuit is configured to operate in a refrigeration cycle in which the pressure of refrigerant discharged from the compressor is at or above the critical pressure.
2. The refrigeration system of claim 1, further comprising a control means that, in performing an operation in which at least one said utilization side heat exchanger in heating operation and at least one said inactive utilization side heat exchanger coexist, fully closes the electric motor-operated valve associated with the at least one inactive utilization side heat exchanger.
3. The refrigeration system of claim 2, wherein when a first specified time t1 has passed since full closure of the electric motor-operated valve associated with the at least one inactive utilization side heat exchanger, the control means temporarily opens the electric motor-operated valve for a second specified time t2.
4. The refrigeration system of claim 3, wherein each of the utilization side heat exchangers is placed in a room and configured to release heat from refrigerant to a room air, room temperature sensors for detecting the temperatures of rooms associated with the respective utilization side heat exchangers are provided around the respective utilization side heat exchangers, and the refrigeration system further comprises a correction means that corrects one or both of the first specified time t1 and the second specified time t2 based on the temperature detected by the room temperature sensor associated with the at least one inactive utilization side heat exchanger.
5. The refrigeration system of claim 2, further comprising refrigerant density detecting devices for detecting the refrigerant densities in the associated utilization side heat exchangers, wherein when the refrigerant density detected by at least one said refrigerant density detecting device associated with the at least one inactive utilization side heat exchanger exceeds a specified refrigerant density after full closure of the electric motor-operated valve associated with the at least one inactive utilization side heat exchanger, the control means temporarily opens the electric motor-operated valve.
6. The refrigeration system of any one of claims 1 to 5, the refrigerant circuit is filled with carbon dioxide as refrigerant.
7. The refrigeration system of any one of claims 2 to 5, further comprising supply openings through which air having passed through the associated utilization side heat exchangers is let out and opening/closing mechanisms for opening and closing the associated supply openings, wherein each of the opening/closing mechanisms is configured to open the supply opening of the associated utilization side heat exchanger when in heating operation and close the supply opening of the associated utilization side heat exchanger when inactive.

FIG. 1

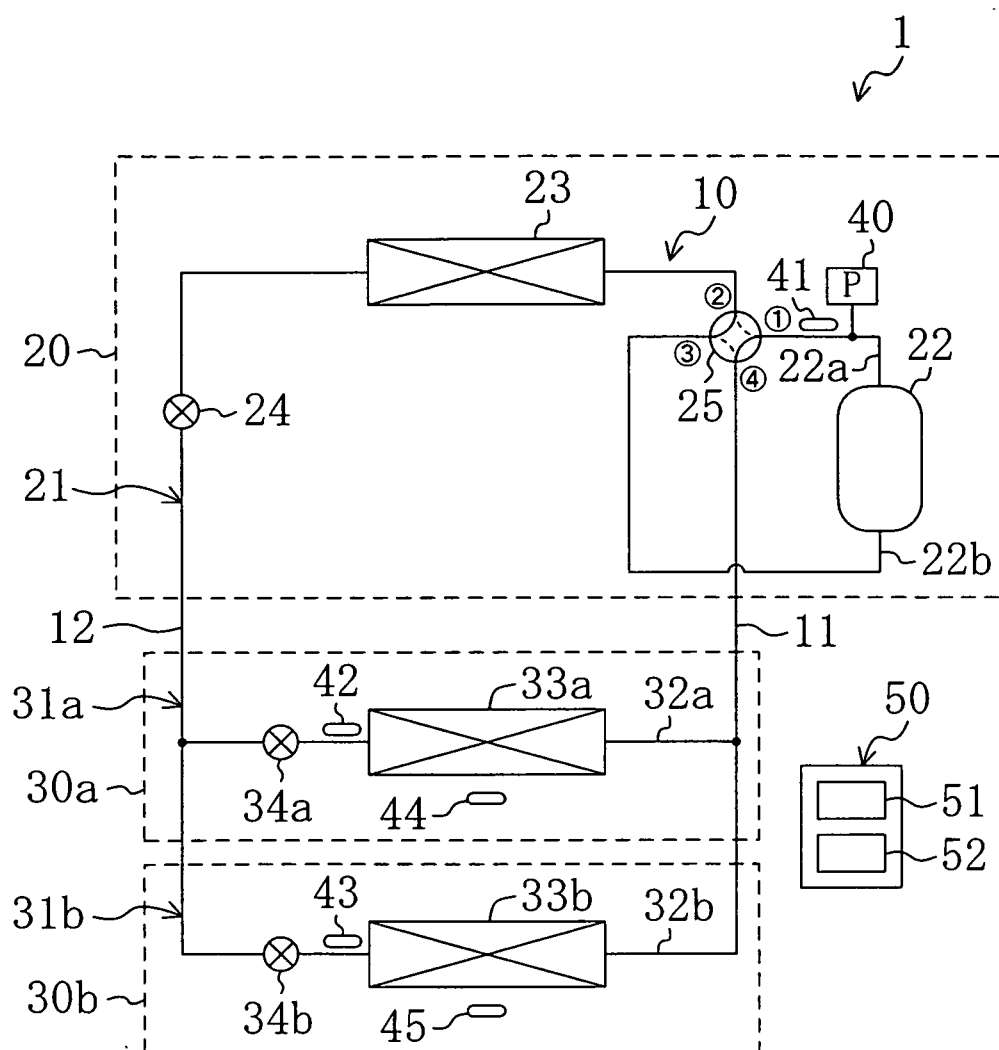


FIG. 2

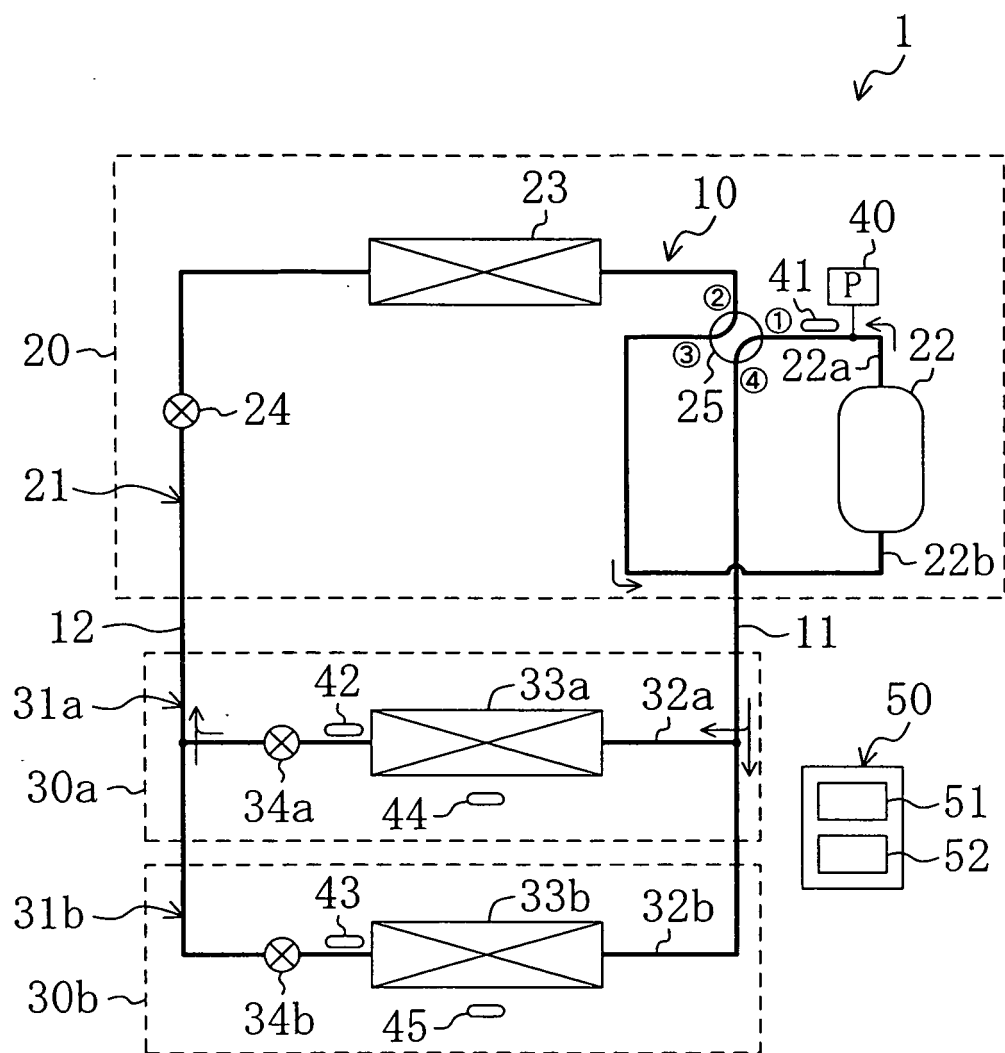


FIG. 3

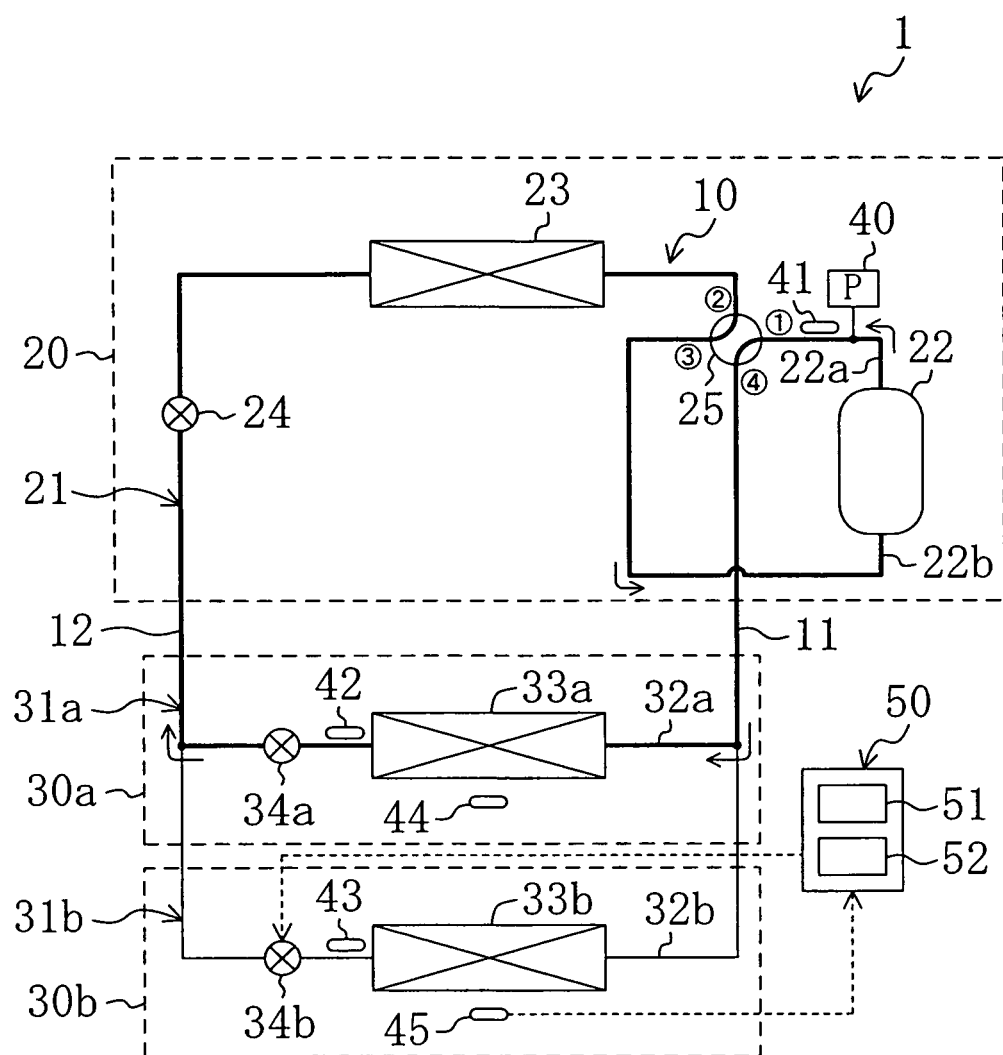


FIG. 4

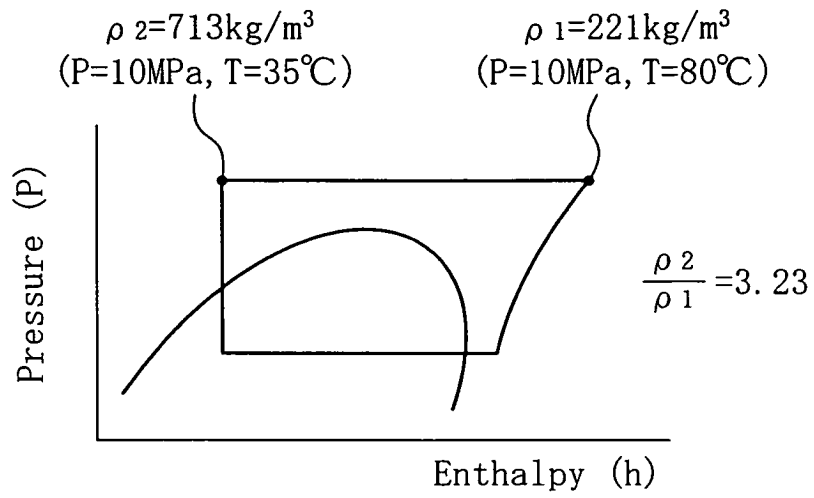


FIG. 5

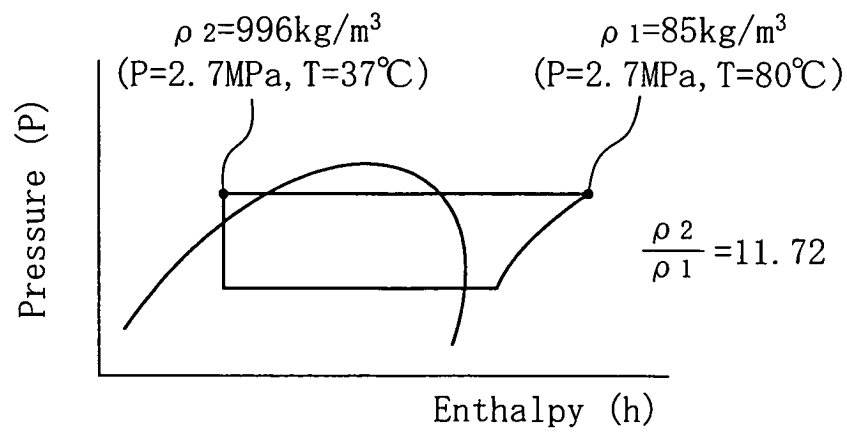


FIG. 6

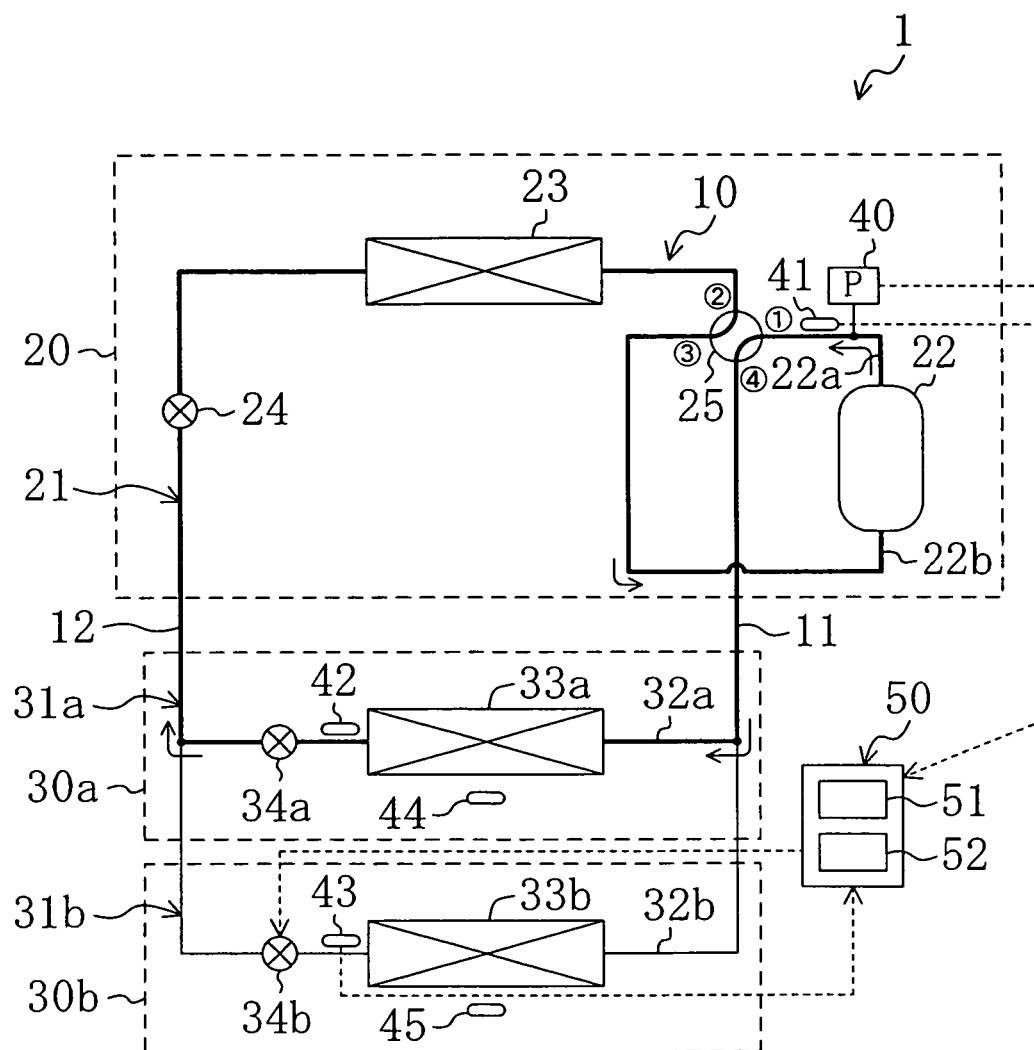


FIG. 7

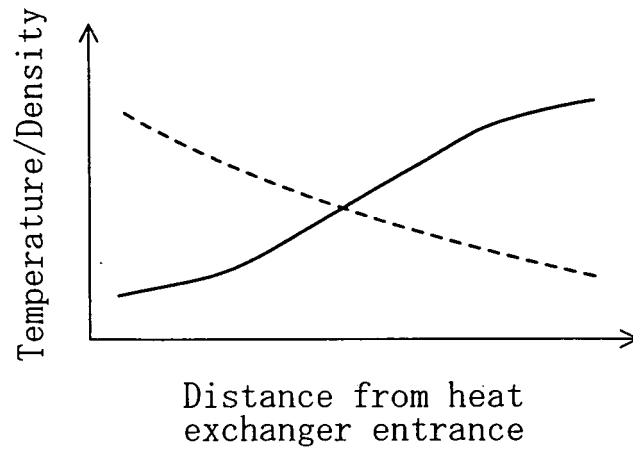
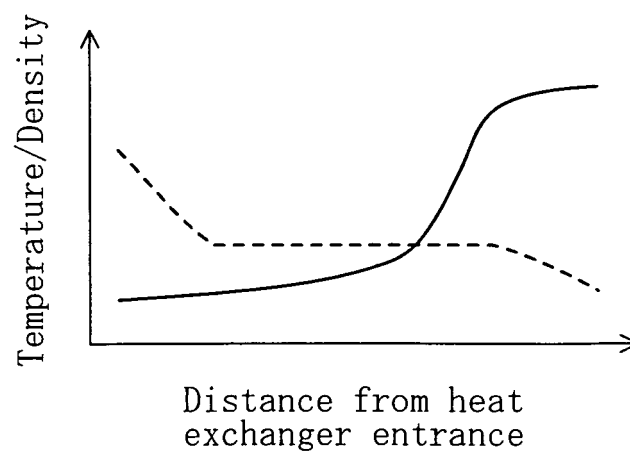


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/054405

A. CLASSIFICATION OF SUBJECT MATTER

F25B6/02(2006.01)i, F24F11/02(2006.01)i, F25B1/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B6/02, F24F11/02, F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2007
Kokai Jitsuyo Shinan Koho	1971-2007	Toroku Jitsuyo Shinan Koho	1994-2007

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2004-232905 A (Sanyo Electric Co., Ltd.), 19 August, 2004 (19.08.04), Par. Nos. [0012] to [0029]; Figs. 1, 2 (Family: none)	1, 6 2, 3, 5, 7 4
Y A	JP 5-312428 A (Daikin Industries, Ltd.), 22 November, 1993 (22.11.93), Claim 1; Fig. 1 (Family: none)	2, 3, 5, 7 4
Y	JP 62-125265 A (Toshiba Corp.), 06 June, 1987 (06.06.87), Page 3, lower right column, line 14 to page 4, upper left column, line 13; Fig. 1 (Family: none)	3, 5

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

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Date of the actual completion of the international search
04 June, 2007 (04.06.07)Date of mailing of the international search report
12 June, 2007 (12.06.07)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/054405

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-201572 A (Matsushita Refrigeration Co.), 30 July, 1999 (30.07.99), Full text; Figs. 1 to 10 (Family: none)	3, 5

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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