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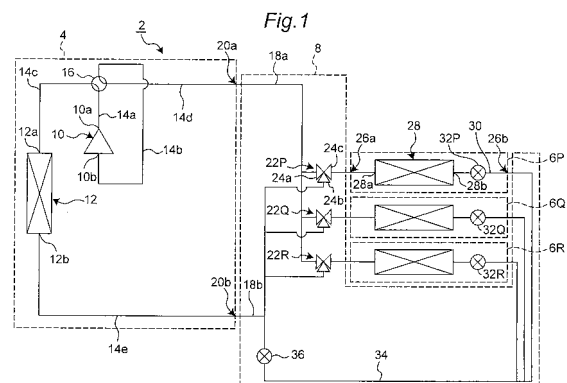
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(54) **AIR CONDITIONER**

(57) One of the aspects of the present invention is to provide an air conditioner including an outdoor unit, a plurality of indoor units, and a relay device for connection between the outdoor unit and each of the indoor units. The outdoor unit includes an outdoor heat exchanger, a compressor for pressurizing a refrigerant of carbon dioxide or a composite having main ingredient of carbon dioxide, and a first switching member for switching a flow direction of the refrigerant through the outdoor heat exchanger, which are in fluid communication between first and second connection ends. Each of the indoor units includes an indoor heat exchanger and a first flow controller which are in fluid communication between first and second pipe connection ports. The relay device includes a plurality of second switching members, each of which the second switching members selectively connects the first pipe connection port of the respective indoor unit with the first or second connection end of the outdoor unit. The relay device also includes a first bypass pipe for connection between the second connection end of the outdoor unit and each of the second pipe connection

ports of the indoor units, and a second flow controller intervening in the first bypass pipe.



Description

BACKGROUND OF THE INVENTION

1) Technical Field of the Invention

[0001] The present invention generally relates to an air conditioner applying a refrigeration cycle. In particular, the present invention relates to a multi-split type air conditioner including an outdoor unit and a plurality of indoor units, performing in operation modes where all of the rooms are cooled and heated, and in other operation modes where one of the rooms is cooled while another one of the rooms is heated, simultaneously.

2) Description of Related Arts

[0002] Patent Document 1 discloses a multi-split type air conditioner, which includes an outdoor unit having a compressor and an outdoor heat exchanger, a plurality of indoor units, each having an indoor heat exchanger, and a relay device for connection between the outdoor unit and the indoor units. The multi-split type air conditioner performs in the cooling and heating operation modes cooling and heating all of the rooms, respectively. Also, it performs in other operation modes cooling one of the rooms while heating another one of the rooms simultaneously, which are referred to as a principally-cooling operation mode where cooling operation capacity is greater than heating operation capacity, and as a principally-heating operation mode where heating operation capacity is greater than cooling operation capacity.

[0003] In the principally-cooling operation mode, the conventional air conditioner requires a vapor-liquid separation device for separating vapor refrigerant and liquid refrigerant from the refrigerant in a vapor-liquid mixed state generated by the outdoor heat exchanger of the outdoor unit. A first bypass pipe has one end connected to a liquid-phase outlet of the vapor-liquid separation device and a plurality of other split ends, each of which connects to a flow control device of the indoor unit. The flow control device of the indoor unit in the room to be cooled depressurizes the high-pressurized liquid refrigerant for changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure, which is supplied to the indoor heat exchanger. On the other hand, the vapor refrigerant output from the vapor-liquid separation device is supplied to the indoor unit of the room to be heated.

Patent Document 1: JP 9-042804, A

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0004] Since the liquid refrigerant output from the vapor-liquid separation device is saturated liquid, unless it is overcooled, it may somehow be depressurized in a

way up to the flow control device of the indoor unit so as to change its phase to the two-phase vapor-liquid phase, thereby causing noise and pressure pulsation in the flow control device. To suppress the problem, i.e., to overcool the saturated liquid refrigerant, a second bypass pipe is arranged adjacent and connected to the first bypass pipe, and another flow control device for controlling the flow through the second bypass pipe, which depressurizes a portion of the liquid refrigerant output from the vapor-liquid separation device to generate the two-phase vapor-liquid refrigerant of low temperature and low pressure, thereby overcooling the liquid refrigerant output from the vapor-liquid separation device with the vapor-liquid refrigerant through the second bypass pipe. Also, in the vapor-liquid separation device, another flow control device intervenes in the first bypass pipe for controlling flow amount of the liquid refrigerant output from the vapor-liquid separation device for preventing the liquid refrigerant from being mixed in the vapor refrigerant.

[0005] As above, the relay device of the conventional air conditioner requires a lot of components. Also, due to too many components, it is difficult to control the cooling and heating capacity of the indoor heat exchangers. The above-described air conditioner uses a fluorocarbon-based refrigerant having high score of the global warming potential that is an index indicating the degree how the greenhouse effect gas brings the global warming, as a basis (=1) for carbon dioxide.

[0006] Therefore, one of the aspects of the present invention is to provide a multi-split type air conditioner using the refrigerant of carbon dioxide, which substantially reduces the number of components of the relay device and improves controllability of the cooling and heating features of the indoor heat exchangers.

MEANS FOR SOLVING THE PROBLEMS

[0007] In order to achieve the above-described objects, an air conditioner of one of the aspects according to the present invention is to provide an air conditioner including an outdoor unit, a plurality of indoor units, and a relay device for connection between the outdoor unit and each of the indoor units. The outdoor unit includes an outdoor heat exchanger, a compressor for pressurizing a refrigerant of carbon dioxide or a composite having main ingredient of carbon dioxide, and a first switching member for switching a flow direction of the refrigerant through the outdoor heat exchanger, which are in fluid communication between first and second connection ends. Each of the indoor units includes an indoor heat exchanger and a first flow controller which are in fluid communication between first and second pipe connection ports. The relay device includes a plurality of second switching members, each of which the second switching members selectively connects the first pipe connection port of the respective indoor unit with the first or second connection end of the outdoor unit. The relay device also includes a first bypass pipe for connection between the

second connection end of the outdoor unit and each of the second pipe connection ports of the indoor units, and a second flow controller intervening in the first bypass pipe.

ADVANTAGE OF THE INVENTION

[0008] In the principally cooling operation mode of the present invention, the refrigerant flows through the refrigerant delivery port of the compressor, the first switching member, the outdoor heat exchanger, and the second connection end into the indoor unit in the room to be heated, in which the refrigerant heats the air in the indoor heat exchanger. After that, the refrigerant flows into the indoor units in the rooms to be cooled, in which after the refrigerant is depressurized when passing through the first flow controller for cooling the air in the indoor heat exchangers of the indoor units, following to the first connection end. The refrigerant of carbon dioxide or a composite having main ingredient of carbon dioxide remains in a supercritical state while flowing from the refrigerant delivery port of the compressor prior to the indoor heat exchangers of the indoor units. Therefore, the noise and the pressure pulsation which might be generated at the first flow controller can be suppressed or avoided. Thus, according to the present invention, since the refrigerant is kept in the supercritical state, unlike the conventional air conditioner, the vapor-liquid separation device 40 and associated components can be eliminated, which substantially reduce the number of the components of the relay device. Also, the controllability of the indoor heat exchanger for heating and cooling the rooms can fairly be improved due to the fewer components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 is a flow circuit of a refrigerant adapted in an air conditioner of the first embodiment of the present invention.

Fig. 2 is the flow circuit similar to Fig. 1, indicating the flow circulation of the refrigerant in a cooling operation mode.

Fig. 3 is the flow circuit similar to Fig. 1, indicating the flow circulation of the refrigerant in a heating operation mode.

Fig. 4 is the flow circuit similar to Fig. 1, indicating the flow circulation of the refrigerant in a principally-cooling operation mode.

Fig. 5 is the flow circuit similar to Fig. 1, indicating the flow circulation of the refrigerant in a principally-heating operation mode.

Fig. 6 is a p-h diagram (pressure-enthalpy diagram) showing transition of the refrigerant illustrated in Fig. 2.

Fig. 7 is a p-h diagram showing transition of the refrigerant illustrated in Fig. 3.

Fig. 8 is a p-h diagram showing transition of the refrigerant illustrated in Fig. 4.

Fig. 9 is a p-h diagram showing transition of the refrigerant illustrated in Fig. 5.

Fig. 10 is a flow circuit of a refrigerant adapted in another air conditioner, as an example for comparison with one of the present invention.

Fig. 11 is a flow circuit of a refrigerant adapted in an air conditioner of the second embodiment of the present invention.

Fig. 12 is the flow circuit similar to Fig. 11, illustrating modification of the second embodiment.

DESCRIPTION OF THE REFERENCE NUMERALS

[0010]

2:	air conditioner
4:	outdoor unit
6P-6R:	indoor unit
8:	relay device
10:	compressor
10a:	refrigerant delivery port
10b:	refrigerant suction port
12:	heat exchanger of an outdoor unit
16:	first switching member (four-way switching valve)
18a, 18b:	first and second inter-unit pipe
20a, 20b:	first and second connection end
26a, 26b:	first and second pipe connection port
28:	heat exchanger of an indoor unit
32P-32R:	first flow controller (flow control valve)
34:	first bypass pipe
36:	second flow controller (flow control valve)
52:	flow-path selector
66:	second bypass pipe
68:	third flow controller (flow control valve)

BEST MODE FOR CARRYING OUT THE INVENTION

[0011] Referring to the attached drawings, the details of embodiments according to the present invention will be described hereinafter.

Embodiment 1.

[0012] Fig. 1 illustrates the first embodiment of an air conditioner according to the present invention. The air conditioner 2 uses carbon dioxide as a refrigerant, and includes, in general, an outdoor unit 4, a plurality of indoor units 6, and a relay device 8 for connection between the outdoor unit 4 and the indoor units 6. While there are shown three of the indoor units 6 (i.e., 6P, 6Q, 6R) in the present embodiment, the present invention cannot be limited by the number of the indoor units 6, as long as the air conditioner has more than two of the indoor units.

[0013] The air conditioner 2 performs in a cooling operation mode in which each of the rooms having the re-

spective indoor unit is to be cooled, and in a heating operation mode in which each of the rooms is to be heated. Also, it performs in another two modes where one of the rooms is cooled while another one of the rooms is heated, simultaneously (i.e., principally-cooling and principally-heating operation modes).

[0014] The indoor unit 4 includes a compressor 10 for compressing the refrigerant, a heat exchanger (outdoor heat exchanger) 12, and a first switching member 16 such as a four-way switching valve, all of which are in fluid communication between first and second connection end 20a, 20b. In particular, the compressor 10 has a refrigerant delivery port 10a and a refrigerant suction port 10b connected to the first switching member 16 via the pipes 14a, 14b, respectively. The first switching member 16 is also connected via the pipe 14d to the first connection end 20a which is in turn connected to a pipe 18a of the relay device 8. Further, the heat exchanger 12 has one end 12a connected to the first switching member 16 via the pipe 14c and the other end connected via the pipe 14e to a second connection end 20b which is in turn connected to another pipe 18b of the relay device 8. As above, the pipes 18a, 18b are referred to as inter-unit pipes for connection between the outdoor unit 4 and the indoor units 6P-6R.

[0015] The switching member 16 is designed to switch a flow direction of the refrigerator through the heat exchanger 12 between first and second flow conditions in accordance with the operation modes. In the first flow condition as illustrated in Fig. 2, the first connection end 20a is connected to the refrigerant suction port 10b of the compressor 10 via the pipes 14d, 14b, and the refrigerant delivery port 10a of the compressor 10 is connected to one end 12a of the heat exchanger 12 via the pipes 14a, 14c, in which the refrigerant flows from one end 12a to the other end 12b of the heat exchanger 12, i.e., from the first connection end 20a to the second connection end 20b. In the second flow condition as illustrated in Fig. 3, one end 12a of the heat exchanger 12 is connected to the refrigerant suction port 10b of the compressor 10 via the pipes 14c, 14b, and the refrigerant delivery port 10a of the compressor 10 is connected to the first connection end 20a via the pipes 14a, 14d, in which the refrigerant flows from the other end 12b to one end 12a of the heat exchanger 12, i.e., from the second connection end 20b to the first connection end 20a.

[0016] A relay device 8 includes a plurality of three-way switching valves (second switching member) 22, e.g., three of the switching valves 22P, 22Q, 22R in the present embodiment, each of which has three of connection ports 24a, 24b, 24c. One inter-unit pipe 18a is split and connected to the connection ports 24a of the switching valves 22P, 22Q, 22R, and the other inter-unit pipe 18b is also split and connected to the connection ports 24b of the switching valves 22P, 22Q, 22R. Also, each of the connection ports 24c of the switching valves 22P, 22Q, 22R is connected to the first pipe connection port 26a of the respective indoor unit 6.

[0017] Each of the indoor units 6 includes another heat exchanger (indoor heat exchanger) 28 and a flow control valve (first flow controller) 32, which are in fluid communication between first and second pipe connection ports 26a, 26b. In particular, the heat exchanger 28 has one end connected via a pipe to the first pipe connection port 26a, and the other end connected via a pipe 30 to the second pipe connection port 26b which is in turn connected to a bypass pipe of the relay member 8. Also, the flow control valves 32 (32P, 32Q, 32R) intervene in the pipe 30 for controlling the flow of the refrigerant there-through.

[0018] As above, the relay device includes the first bypass pipe 30 having one end connected to the inter-unit pipe 18b and the other end split and connected to each of the second pipe connection ports 26b (and the flow control valves 32). Also, a second flow control valve 36 intervenes in the bypass pipe 30 for controlling the flow of refrigerant through the bypass pipe 30.

[0019] Next, the operation of the air conditioner 2 so structured will be described herein, with reference to Figs. 2-5 illustrating the flow of the refrigerant and Figs. 6-9 of the p-h diagram showing the relationship between the pressure and the enthalpy of the refrigerant. In Figs. 2-5, the thick lines indicate pipes through which the refrigerant is running and the bracket indexes [i] (i = 1, 2, ...) shows positions where the phases of the refrigerant are illustrated by plotting the points with the bracket indexes [i] on the diagrams in Figs. 6-9.

<<Cooling Operation Mode (Figs. 2 and 6)>>

[0020] When all of the indoor units 6P-6R perform the cooling operation, the switching member 16 switches to the first flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with one end 12a of the heat exchanger 12 and by connecting the refrigerant suction port 10b with the first connection end 20a), the second flow control valve 36 is fully opened, and the first flow control valves 32P-32R is throttled. Also, the connection port 24b of the three-way switching valve 22 is closed while the connection ports 24a, 24c are opened. In this arrangement, the compressor 10 initiates to be driven.

[0021] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant is pressurized adiabatically, i.e., without heat exchange with ambient air, which is described by a constant-enthalpy line [1]-[2] in the p-h diagram (pressure-enthalpy diagram) of Fig. 6.

[0022] The refrigerant of high pressure and high temperature flows through the first switching member 16 and heats the ambient air in the heat exchanger 12 to lower the temperature of the refrigerant. The pressure thereof is kept almost constant but slightly declining due to pressure loss in the heat exchanger 12 as the refrigerant is

cooled, which is represented by a almost flat line [2]-[3] in the p-h diagram. Unlike the fluorocarbon-based refrigerant, the refrigerant of carbon dioxide according to the present invention is kept in a supercritical state at high temperature and lowers the temperature without condensation.

[0023] The refrigerant from the heat exchanger 12 flows through the second connection end 20b and the bypass pipe 34, while the flow control valve 36 is fully opened, into each of the indoor units 6P-6R, in which throttling the flow control valves 32P-32R changes (depressurizes) the refrigerant to the two-phase vapor-liquid refrigerant of low temperature and low pressure. The refrigerant is depressurized at the flow control valves 32P-32R under the constant enthalpy, which is represented by a vertical line [3]-[4] of the p-h diagram.

[0024] As the two-phase vapor-liquid refrigerant of low temperature and low pressure is changing to the vapor refrigerant of low temperature and low pressure, it refrigerates (absorbs heat from) the ambient air in the heat exchanger 28. The pressure of the refrigerant is kept almost constant but slightly declining due to pressure loss in the heat exchanger 28 as the refrigerant absorbs heat, which is represented by a almost flat line [4]-[1] in the p-h diagram.

[0025] The vapor refrigerant of low temperature and low pressure from the heat exchanger 28 returns through the three-way switching valves 22, the first connection end 20a, and the first switching member 16, into the compressor 10.

[0026] It should be noted that while the pressure of the vapor refrigerant immediately after coming out of the heat exchanger 28 becomes lower than that of the refrigerant just before coming in the compressor 10 during transfer through the pipes, the vapor refrigerant is represented by the same point [1]. Similarly, while the high pressure of the refrigerant just before the flow control valve 32 is slightly less than that of the refrigerant right after the heat exchanger 12, the refrigerant is represented by the same point [3]. The slight pressure reduction of the refrigerant and the pressure loss in the heat exchangers 12, 28 are observed also in the heating operation mode, and the principally-cooling and principally-heating operation modes, as will be described herein, thus, duplicate explanation will be eliminated, unless necessary.

<<Heating Operation Mode (Figs. 3 and 7)>>

[0027] When all of the indoor units 6P-6R perform the heating operation, the switching member 16 switches to the second flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with the first connection end 20a and by connecting the refrigerant suction port 10b with one end 12a of the heat exchanger 12), the second flow control valve 36 is fully opened, and the first flow control valves 32P-32R is throttled. Also, the connection port 24b of the three-way switching valve 22 is closed while the connection ports 24a, 24c are opened.

In this arrangement, the compressor 10 initiates to be driven.

[0028] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature (point [1]) to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature (point [2]) flows through the first switching member 16, the first connection end 20a, and the three-way switching valves 22 into each one of the heat exchangers 28 of the indoor units 6P-6R. The refrigerant heats the ambient air in the heat exchangers 28 thereby to lower the temperature of the refrigerant (point [3]), and is depressurized by the flow control valve 32 to be changed as the two-phase vapor-liquid refrigerant of low temperature and low pressure (point [4]). Then, the refrigerant from each of the indoor units 6P-6R flows through the bypass pipe 34 and the second connection end 20b to the other end 12b of the heat exchanger 12. The two-phase vapor-liquid refrigerant refrigerates (absorbs heat from) the ambient air in the heat exchanger 12 to be the vapor refrigerant of low temperature and low pressure (point [1]), which returns to the compressor 10 through the switching member 16.

<<Principally Cooling Operation Mode (Figs. 4 and 8)>>

[0029] When two of the indoor units 6P, 6Q perform the cooling operation and one of the indoor unit 6R performs the heating operation, the switching member 16 switches to the first flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with one end 12a of the heat exchanger 12 and by connecting the refrigerant suction port 10b with the first connection end 20a). Also, the second flow control valve 36 is closed, and the first flow control valves 32P and 32Q are throttled, while the valve 32R is fully opened. Further, each of the three-way switching valves 22P and 22Q has the connection port 24b being closed and the connection ports 24a and 24c being opened. The three-way switching valve 22R has the connection port 24a being closed and the connection ports 24b and 24c being opened. In this arrangement, the compressor 10 initiates to be driven.

[0030] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature (point [1]) to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature (point [2]) flows through the first switching member 16 to the heat exchanger 12, heating the ambient air in the heat exchanger 12 thereby to lower the temperature of the refrigerant (point [3]).

[0031] The refrigerant of high pressure from the heat exchanger 12 flows through the second connection end 20b and the three-way switching valve 22R into the indoor unit 6R to heat the ambient air in the heat exchanger 28 to lower the temperature of the refrigerant (point [4]). Then, the refrigerant is depressurized by the flow control

valve 32P and 32Q to be the two-phase vapor-liquid refrigerant of low temperature and low pressure (point [5]). The refrigerant refrigerates (absorbs heat from) the ambient air in the heat exchanger 28 of the indoor units 6P, 6Q, changing to the vapor refrigerant of low temperature and low pressure (point [1]).

[0032] The refrigerant from the indoor units 6P, 6Q passes through the three-way switching valve 22P and 22Q, the first connection end 20a, and the switching member 16, and returns to the compressor 10.

[0033] The refrigerant of carbon dioxide according to the present invention can be kept in a supercritical state while flowing from the refrigerant delivery port 10a of the compressor 10 through the first switching member 16, the indoor heat exchanger 12, the indoor unit 6R, and the flow control valves 32P and 32Q of the indoor units 6P and 6Q. Therefore, noise and pressure pulsation can be avoided or reduced, which might otherwise be generated at the flow control valves 32P and 32Q of the indoor units 6P and 6Q.

[0034] In the meanwhile, as a comparative example, a conventional air conditioner using the fluorocarbon-based refrigerant will be described herein and illustrated in Fig. 10. The air conditioner 2' includes the vapor-liquid separation device intervening in the inter-unit pipe 18b within the relay device 8', and the bypass pipe 34 is connected to the liquid-phase port of the vapor-liquid separation device 40.

[0035] When the conventional air conditioner performs in the principally cooling operation mode, i.e., when two of the indoor units 6P, 6Q perform the cooling operation and one of the indoor unit 6R performs the heating operation, the switching member 16 switches to the first flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with one end 12a of the heat exchanger 12 and by connecting the refrigerant suction port 10b with the first connection end 20a). Also, the second flow control valve 36 and the first flow control valves 32P, 32Q are throttled, while the valve 32R is fully opened. Further, each of the three-way switching valves 22P, 22Q has the connection port 24b being closed and the connection ports 24a, 24c being opened. The three-way switching valve 22R has the connection port 24a being closed and the connection ports 24b and 24c being opened. In this arrangement, the compressor 10 initiates to be driven.

[0036] Pressurization by the compressor 10 changes the fluorocarbon-based vapor refrigerant of low pressure and low temperature (point [1]) to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature flows through the first switching member 16 to the heat exchanger 12, in which the refrigerant heats the ambient air in the heat exchanger 12 to partially condense thereby to be the two-phase vapor-liquid refrigerant of high pressure, since the pressure of the refrigerant coming into the heat exchanger 12 is lower than the critical pressure. The two-phase vapor-liquid re-

frigerant from the heat exchanger 12 enters the vapor-liquid separation device 40. The vapor refrigerant runs through the three-way valve 22R into the heat exchanger 28 of the indoor unit 6R, in which the vapor refrigerant heats the ambient air in the heat exchanger 28 to condense, thereby changing to the liquid refrigerant of high pressure that passes through the flow control valve 32R. Meanwhile, another liquid refrigerant in the vapor-liquid separation device 40 flows through the flow control valve 36 and joins with the former liquid refrigerant from the indoor unit 6R, both of which liquid refrigerant come into the indoor units 6P, 6Q. Then, the refrigerant is depressurized by the flow control valve 32P, 32Q, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure. The refrigerant refrigerates (absorbs heat from) the ambient air in the heat exchanger 28, further changing to the vapor refrigerant of low temperature and low pressure. The refrigerant from the indoor units 6P, 6Q passes through the three-way switching valve 22P, 22Q and the switching member 16, and returns to the compressor 10.

[0037] The flow control valve 36 controls the flow amount of the liquid refrigerant running from the vapor-liquid separation device 40 so that the vapor refrigerant running from the vapor-liquid separation device 40 into the indoor unit 6R contains no liquid refrigerant. Thus, the liquid refrigerant is depressurized when passing through the flow control valve 36 and the bypass pipe 34. As the liquid refrigerant running from the vapor-liquid separation device 40 is the saturated refrigerant, it can be the two-phase vapor-liquid refrigerant by depressurization, which causes noise and pressure pulsation generated when the vapor-liquid refrigerant passes the flow control valves 33P, 33Q of the indoor units 6P, 6Q.

[0038] To address the drawback, the conventional air conditioner 2' requires a feature designed for overcooling the liquid refrigerant running from the vapor-liquid separation device 40. In particular, a second bypass pipe 42 is arranged adjacent the first bypass pipe 34, which has one end connected to a portion of the first bypass pipe 34 downstream of the flow control valve 36 and the other end connected to the inter-unit pipe 18a. Also, another flow control valve 44 is provided intervening in the second bypass pipe 42. This allows the liquid refrigerant at the flow control valve 44 to expand (depressurize) by throttling the flow control valve 44 thereby to obtain the two-phase vapor-liquid refrigerant of low temperature and low pressure. The second bypass pipe 42 with the vapor-liquid refrigerant overcools the refrigerant through the first bypass pipe 34 in regions between the vapor-liquid separation device 40 and the flow control valve 36 and between the flow control valve 36 and the connection portion.

[0039] As above, when the fluorocarbon-based refrigerant is used in the air conditioner, too many components have to be incorporated into the relay device 8'.

[0040] On the contrary, according to the present embodiment of the invention, a substantial number of com-

ponents of the relay device 8' can be eliminated by using the refrigerant of carbon dioxide. Also, fewer number of flow control valves improves controllability of the cooling and heating capacity for the indoor heat exchangers 32P-32R.

[0041] It should be noted that while in the principally cooling operation mode of the present embodiment, the flow control valve 36 is closed so that all of the refrigerant flows the indoor unit 6R heating the room, the flow control valve 36 may be adjusted so that a portion of the refrigerant passes through the first bypass pipe 34, bypassing the indoor unit 6R. This prevents increase of the refrigerant flow, which may cause the refrigerant noise and the corrosion of the pipe.

<<Principally Heating Operation Mode (Figs. 5 and 9)>>

[0042] When two of the indoor units 6P, 6Q perform the heating operation and one of the indoor unit 6R performs the cooling operation, the switching member 16 switches to the second flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with the first connection end 20a and by connecting the refrigerant suction port 10b with one end 12a of the heat exchanger 12). Also, the second flow control valve 36 is throttled, and the first flow control valves 32P, 32Q are fully opened, while the first flow control valve 32R is throttled. Further, each of the three-way switching valves 22P, 22Q has the connection port 24b being closed and the connection ports 24a, 24c being opened. The three-way switching valve 22R has the connection port 24a being closed and the connection ports 24b and 24c being opened. In this arrangement, the compressor 10 initiates to be driven.

[0043] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature (point [1]) to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature (point [2]) flows through the first switching member 16 and the three-way switching valve 22P, 22Q to the heat exchangers 28 of the indoor units 6P, 6Q, heating the ambient air in the heat exchangers 28 thereby to lower the temperature of the refrigerant (point [3]). After flowing through the heat exchangers 28 and the flow control valves 32P and 32Q of the indoor units 6P and 6Q, a portion of the refrigerant runs towards the indoor unit 6R and the remaining portion thereof bypasses the indoor unit 6R through the bypass pipe 34.

[0044] The refrigerant entering the indoor unit 6R expands (depressurizes) at the flow control valve 32R, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure (point [4]). Also, the refrigerant all or partially evaporates to refrigerate the ambient air in the heat exchanger 28 (point [5]) and enters the three-way switching valves 22R. Although not limited thereto, according to the present embodiment of Fig. 9, the refrigerant passing out of the heat exchanger 28

(point [5]) is the two-phase vapor-liquid refrigerant having the dryness close to 1.0.

[0045] On the other hand, the remaining portion of the refrigerant (point [3]) bypasses the indoor unit 6R through the bypass pipe 34 and expands (depressurizes) at the flow control valve 36, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure (point [6]). Although not limited thereto, according to the present embodiment of Fig. 9, the refrigerant passing out of the flow control valve 36 (point [6]) has the pressure slightly less than that of the refrigerant passing out of the heat exchanger 28 (point [5]).

[0046] The refrigerant passing out of the flow control valve 36 and the refrigerant passing out of the three-way control valve 22R join to be the two-phase vapor-liquid refrigerant (point [7]), which flows through the second connection end 20b of the outdoor unit 4 to the heat exchanger 12. Also, the two-phase vapor-liquid refrigerant refrigerates the ambient air in the heat exchanger 12, changing to the vapor refrigerate (point [1]), which passes through the switching member 16 back to the compressor 10.

[0047] As above, the air conditioner according to the present embodiment controls the refrigerant flow passing through the indoor unit that performs the cooling operation with adjustment of the flow control valve 36, thereby improving the operation efficiency.

Embodiment 2.

[0048] Fig. 11 illustrates the second embodiment of an air conditioner according to the present invention. The outdoor unit 4A of the air conditioner 2A includes a flow-path selecting member 52 in addition to the structure of the air conditioner 2 of the first embodiment. The flow-path selecting member 52 is designed such that the refrigerant flows from the outdoor unit 4A into the relay device 8A always through the second connection end 20b, and from the relay device 8A to the outdoor unit 4A always through the first connection end 20a, regardless of the operation modes.

[0049] In particular, the flow-path selecting member 52 includes a pair of check valves 54, 56, intervening in the pipes between the first switching member 16 and the first connection end 20a, and between the heat exchanger 12 and the second connection end 20b, respectively. The check valve 54 allows the refrigerant to flow only in a direction from the first connection end 20a to the switching member 16, and the check valve 56 allows the refrigerant to flow only in a direction from the heat exchanger 12 to the second connection end 20b.

[0050] Also, the flow-path selecting member 52 includes a bypass pipe 58 having one end connected to an intermediate point of the pipe 14d between the switching member 16 and check valve 54 and the other end connected to the second connection end 20b. A check valve 60 is provided intervening in the bypass pipe 58, which allows the refrigerant to flow only in a direction

from the switching member 16 to the second connection end 20b. Further, the flow-path selecting member 52 includes a bypass pipe 62 having one end connected to the first connection end 20a and the other end connected to an intermediate point of the pipe 14e between the heat exchanger 12 and the check valves 56. A check valve 60 is provided intervening in the bypass pipe 62, which allows the refrigerant to flow only in a direction from the first connection end 20a to the heat exchanger 12.

[0051] The relay device 8A includes a second bypass pipe 66 connecting between the first bypass pipe 34 and the inter-unit pipe 18a, and a third flow control valve 68 intervening in the second bypass pipe 66 for controlling the refrigerant flow running therethrough.

[0052] Next, each of the operation modes performed by the air conditioner 2A' so structured will be described herein.

<<Cooling Operation Mode>>

[0053] When all of the indoor units 6P-6R perform the cooling operation, the switching member 16 switches to the first flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with one end 12a of the heat exchanger 12 and by connecting the refrigerant suction port 10b with the first connection end 20a), the second flow control valve 36 is fully opened, and the first flow control valves 32P-32R is throttled, while the third flow control valve 68 is closed. Also, the connection ports 24b of the three-way switching valves 22 are closed while the connection ports 24a, 24c are opened. In this arrangement, the compressor 10 initiates to be driven.

[0054] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature flows through the first switching member 16 into the heat exchanger 12, heating the ambient air in the heat exchanger 12 thereby to lower the temperature of the refrigerant without condensation. The refrigerant of high pressure from the heat exchanger 12 flows through the check valve 56, the second connection end 20b, and the first bypass pipe 34 (the second flow control valve 36 is fully opened) to the indoor units 6P-6R, in which the refrigerant expands (depressurizes) at the flow control valves 32P-32R, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure. The refrigerant refrigerates (absorbs heat from) the ambient air in the heat exchanger 28, changing to the vapor refrigerant of low temperature and low pressure. The refrigerant from the heat exchangers 28 of the indoor units 6P-6R flows through the three-way switching valve 22P-22R and the first connection end 20a. The refrigerant at the first connection end 20a has pressure less than the refrigerant between the heat exchanger 12 and the check valve 64 so that it is automatically guided to pass through the check valve 54 and the first switching member 16 back

to the compressor 10.

<<Heating Operation Mode>>

[0055] When all of the indoor units 6P-6R perform the heating operation, the switching member 16 switches to the second flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with the first connection end 20a and by connecting the refrigerant suction port 10b with one end 12a of the heat exchanger 12), the second flow control valve 36 is fully opened, and the first flow control valves 32P-32R is throttled while the third flow control valve 68 is fully opened. Also, the connection port 24a of the three-way switching valve 22 is closed while the connection ports 24b, 24c are opened. In this arrangement, the compressor 10 initiates to be driven.

[0056] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature flows through the first switching member 16, the check valve 60, the second connection end 20b, and the three-way switching valves 22 to each one of the heat exchangers 28 of the indoor units 6P-6R. The refrigerant heats the ambient air in the heat exchangers 28 to lower the temperature of the refrigerant, and is depressurized by the flow control valve 32, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure. Then, the refrigerant from each of the indoor units 6P-6R flows through the first bypass pipe 34 and the third flow control valve 68 (the second bypass pipe 66) into the first connection end 20a. The refrigerant at the first connection end 20a has pressure less than the refrigerant between the switching member 16 and the check valve 54 so that it is automatically guided through the check valve 64 to the other end 12b of the heat exchanger 12. The two-phase vapor-liquid refrigerant refrigerates (absorbs heat from) the ambient air in the heat exchanger 12, changing to the vapor refrigerant of low temperature and low pressure, which runs through the switching member 16 back to the compressor 10.

<<Principally Cooling Operation Mode>>

[0057] When two of the indoor units 6P, 6Q perform the cooling operation and one of the indoor unit 6R performs the heating operation, the switching member 16 switches to the first flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with one end 12a of the heat exchanger 12 and by connecting the refrigerant suction port 10b with the first connection end 20a). Also, the second and third flow control valves 36, 68 are closed, and the first flow control valves 32P, 32Q are throttled, while the first flow control valve 32R is fully opened. Further, each of the three-way switching valves 22P, 22Q has the connection port 24b being closed and the connection ports 24a and 24c being opened. The

three-way switching valve 22R has the connection port 24a being closed and the connection ports 24b, 24c being opened. In this arrangement, the compressor 10 initiates to be driven.

[0058] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature flows through the first switching member 16 into the heat exchanger 12, heating the ambient air in the heat exchanger 12 thereby to lower the temperature of the refrigerant. The refrigerant of high pressure from the heat exchanger 12 flows through the check valve 56, the second connection end 20b, and the three-way switching valve 22R into the indoor unit 6R, heating the ambient air in the heat exchanger 28 thereby to lower the temperature of the refrigerant. Then, the refrigerant is depressurized by the flow control valve 32P, 32Q, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure. The refrigerant refrigerates (absorbs heat from) the ambient air in the heat exchanger 28 of the indoor units 6P, 6Q, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure. The refrigerant from the indoor units 6P, 6Q passes through the three-way switching valve 22P, 22Q into the first connection end 20a. The refrigerant at the first connection end 20a has pressure less than the refrigerant between the heat exchanger 12 and the check valve 64 so that it is automatically guided to pass through the check valve 54 and the switching member 16 back to the compressor 10.

[0059] It should be noted that while in the principally cooling operation mode of the second embodiment, the flow control valve 36 is closed so that all of the refrigerant flows into the indoor unit 6R heating the room, the flow control valve 36 may be adjusted so that a portion of the refrigerant passes through the first bypass pipe 34 bypassing the indoor unit 6R. This prevents increase of the refrigerant flow, which may cause the refrigerant noise and the corrosion of the pipe.

<<Principally Heating Operation Mode>>

[0060] When two of the indoor units 6P, 6Q perform the heating operation and one of the indoor unit 6R performs the cooling operation, the switching member 16 switches to the second flow condition (by connecting the refrigerant delivery port 10a of the compressor 10 with the first connection end 20a and by connecting the refrigerant suction port 10b with one end 12a of the heat exchanger 12). Also, the second flow control valve 36 is closed, and the first flow control valves 32P, 32Q are fully opened, while the first flow control valve 32R and the third flow control valve 68 are throttled. Further, each of the three-way switching valves 22P, 22Q has the connection port 24a being closed and the connection ports 24b, 24c being opened. The three-way switching valve 22R has the connection port 24b being closed and the

connection ports 24a, 24c being opened. In this arrangement, the compressor 10 initiates to be driven.

[0061] Pressurization by the compressor 10 changes the vapor refrigerant of low pressure and low temperature to one of high pressure and high temperature, which is delivered from the refrigerant delivery port 10a. The refrigerant of high pressure and high temperature flows through the first switching member 16 and the three-way switching valve 22P, 22Q into the heat exchangers 28 of the indoor units 6P and 6Q, heating the ambient air in the heat exchangers 28 thereby to lower the temperature of the refrigerant. After flowing through the heat exchangers 28 and the flow control valves 32P, 32Q of the indoor units 6P, 6Q, a portion of the refrigerant runs towards the indoor unit 6R and the remaining portion thereof passes through the bypass pipe 34.

[0062] The refrigerant entering the indoor unit 6R expands (depressurizes) at the flow control valve 32R, changing to the two-phase vapor-liquid refrigerant of low temperature and low pressure. Also, the refrigerant all or partially evaporates to refrigerate the ambient air in the heat exchanger 28 and enters the three-way switching valves 22R.

[0063] On the other hand, the remaining portion of the refrigerant bypassing the indoor unit 6R passes through the first and second bypass pipes 34, 66 and expands (depressurizes) at the flow control valve 68 to be two-phase vapor-liquid refrigerant of low temperature and low pressure. The refrigerant passing out of the flow control valve 68 joins with the refrigerant passing out of the three-way control valve 22R to be the two-phase vapor-liquid refrigerant, which flows into the first connection end 20a of the outdoor unit 4. The refrigerant at the first connection end 20a has pressure less than the refrigerant between the switching member 16 and the check valve 54 so that it is automatically guided to return through the check valve 64 to the other end 12a of the heat exchanger 12. The two-phase vapor-liquid refrigerant refrigerates the ambient air in the heat exchanger 12 to change itself to be vapor refrigerant of low temperature and low pressure in the heat exchanger 12, which returns through the switching member 16 to the compressor 10.

[0064] The air conditioner of the present embodiment has another advantage in addition to those of the first embodiment. That is, a pair of the inter-unit pipes connecting between the outdoor unit 4A and the indoor unit 6P-6R can be designed such that the refrigerant of high pressure flows only through one of the pipes 18b, and the refrigerant of low pressure flows only through the other one of the pipes 18a. Therefore, the inter-unit pipe 18a may have the pipe wall thickness less than that of the inter-unit pipe 18b.

[0065] The three-way switching valve is used in the second embodiment. Alternatively, a pair of two-way valves 22, 23 may be adapted as illustrated in Fig. 12. In particular, the two-way valve 22 has one end connected to the inter-unit pipe 18a and the second bypass pipe 66, and the other end connected to the indoor unit 28.

Also, the another two-way valve 23 has one end connected to the inter-unit pipe 18b and the other end connected to the indoor unit 28. To this end, similar to the second embodiment, the flow directions of the refrigerant running through the inter-unit pipes 18a, 18b (and the two-way valves 22, 23) can be kept the same regardless the operation modes.

[0066] Although not limited thereto, several embodiments have been explained above solely for purpose to describe the present invention, and the embodiments can be changed and modified without departing the scope of the present invention. For example, the switching member may have any other structures rather than the three-way control valves 22P-22R, for selectively connecting the indoor heat exchanger 28 with the pipe 18a or 18b.

[0067] Also, in the second embodiment, the flow-path selecting member 52 may have any other structures for allowing the refrigerant to flow from the outdoor unit 4A to the relay device 8A only through the connection end 20b and from the relay device 8A to the outdoor unit 4A only through the connection end 20a, in which the present invention is not limited to the structure shown in Fig. 11. Thus, when the switching member 16 switches to the first flow condition by connecting the refrigerant delivery port 10a of the compressor 10 with one end 12a of the heat exchanger 12 and by connecting the refrigerant suction port 10b with the first connection end 20a, the flow-path selecting member 52 guides the refrigerant from the end 12b of the heat exchanger 12 to the connection end 20b and blocks it to the connection end 12a. Also, when the switching member 16 switches to the second flow condition by connecting the refrigerant delivery port 10a of the compressor 10 with the first connection end 20a and by connecting the refrigerant suction port 10b with one end 12a of the heat exchanger 12, the flow-path selecting member 52 guides the refrigerant from the compressor 10 to the connection end 20b and blocks it to the connection end 12a. Any types of the flow-path selecting members having such structures are included in the present invention.

[0068] In the above embodiments, carbon dioxide itself is used as the refrigerant, however, any composites having main ingredient of carbon dioxide may be used as the refrigerant.

[0069] The term "unit" in the indoor and outdoor units is not intended to describe that all components are physically provided within or on the same housing. For instance, the structure having the flow control valve of the indoor unit located at a position remote from the housing in which the indoor heat exchanger 28 is provided, also falls within the scope of the present invention. Also, a plurality of pairs of outdoor heat exchangers and the compressors may be provided within the outdoor unit so that the refrigerant from each pairs of outdoor heat exchangers and the compressors join to flow from one of the inter-unit pipes, and the refrigerant from the other end of the inter-unit pipes is split to each pair of outdoor heat exchangers and the compressors.

Claims

1. An air conditioner, comprising:

5 an outdoor unit including an outdoor heat exchanger, a compressor for pressurizing a refrigerant of carbon dioxide or a composite having main ingredient of carbon dioxide, and a first switching member for switching a flow direction of the refrigerant through the outdoor heat exchanger, which are in fluid communication between first and second connection ends;
10 a plurality of indoor units, each of said indoor units including an indoor heat exchanger and a first flow controller which are in fluid communication between first and second pipe connection ports; and
15 a relay device including a plurality of second switching members, each of the second switching members selectively connecting the first pipe connection port of the respective indoor unit with either one of the first and second connection ends of the outdoor unit, a first bypass pipe for connection between the second connection end of the outdoor unit and each of the second pipe connection ports of the indoor units, and a second flow controller intervening in the first bypass pipe.

30 2. The air conditioner according to Claim 1, wherein the compressor has a refrigerant delivery port and a refrigerant suction port; and wherein the first switching member switches in accordance with the operation modes of the air conditioner between first and second conditions, the first condition allowing connection of the refrigerant delivery port with one end of the outdoor heat exchanger and connection of the refrigerant suction port with the first connection end, the second condition allowing connection of the refrigerant delivery port with the first connection end and connection of the refrigerant suction port with said one end of the outdoor heat exchanger.

45 3. The air conditioner according to Claim 1, wherein when the first switching member switches to the first and second conditions, the refrigerant heats air in the outdoor heat exchanger and the indoor heat exchanger, respectively, while remaining in a supercritical state without condensation.

50 4. The air conditioner according to Claim 1, further comprising:

55 a flow-path selector for guiding the refrigerant from the outdoor heat exchanger to the second connection end and guiding the refrigerant from the first connection end to the refrigerant suction

- port when the first switching member switches to the first condition, and for guiding the refrigerant from the refrigerant delivery port to the second connection end and guiding the refrigerant from the first connection end to the outdoor heat exchanger when the first switching member switches to the second condition;
 a second bypass pipe for fluid communication between the first connection end of the outdoor unit and the first bypass pipe; and
 a third flow controller intervening in the second bypass pipe.
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5. The air conditioner according to Claim 4, wherein the flow-path selector includes a first check valve intervening in a first path between the first connection end and the compressor, a second check valve intervening in a second path between the second connection end and the outdoor heat exchanger, a third check valve intervening in a third path between the first connection end and the outdoor heat exchanger, and a fourth check valve intervening in a fourth path between the second connection end and the compressor.
 6. The air conditioner according to Claim 4, wherein the second switching member connects to the first and second connection ends through first and second inter-unit pipes, respectively; and wherein the first inter-unit pipe has a pipe wall thickness thinner than that of the second inter-unit pipe.
 7. The air conditioner according to Claim 1, wherein the first switching member and each of the second switching members are operable independently upon the other switching members.
 8. The air conditioner according to Claim 1, wherein the first switching member includes a four-way switching valve.
 9. The air conditioner according to Claim 1, wherein each of the second switching members includes a three-way switching valve connected to the first and second connection ends of the outdoor unit and the first pipe connection port of the respective indoor unit.
 10. The air conditioner according to Claim 1, wherein each of the second switching members includes a first two-way switching valve connected to the first connection end of the outdoor unit and the first pipe connection port of the respective indoor unit, and a second two-way switching valve connected to the second connection end of the outdoor unit and the first pipe connection port of the respective indoor unit.

Fig.1

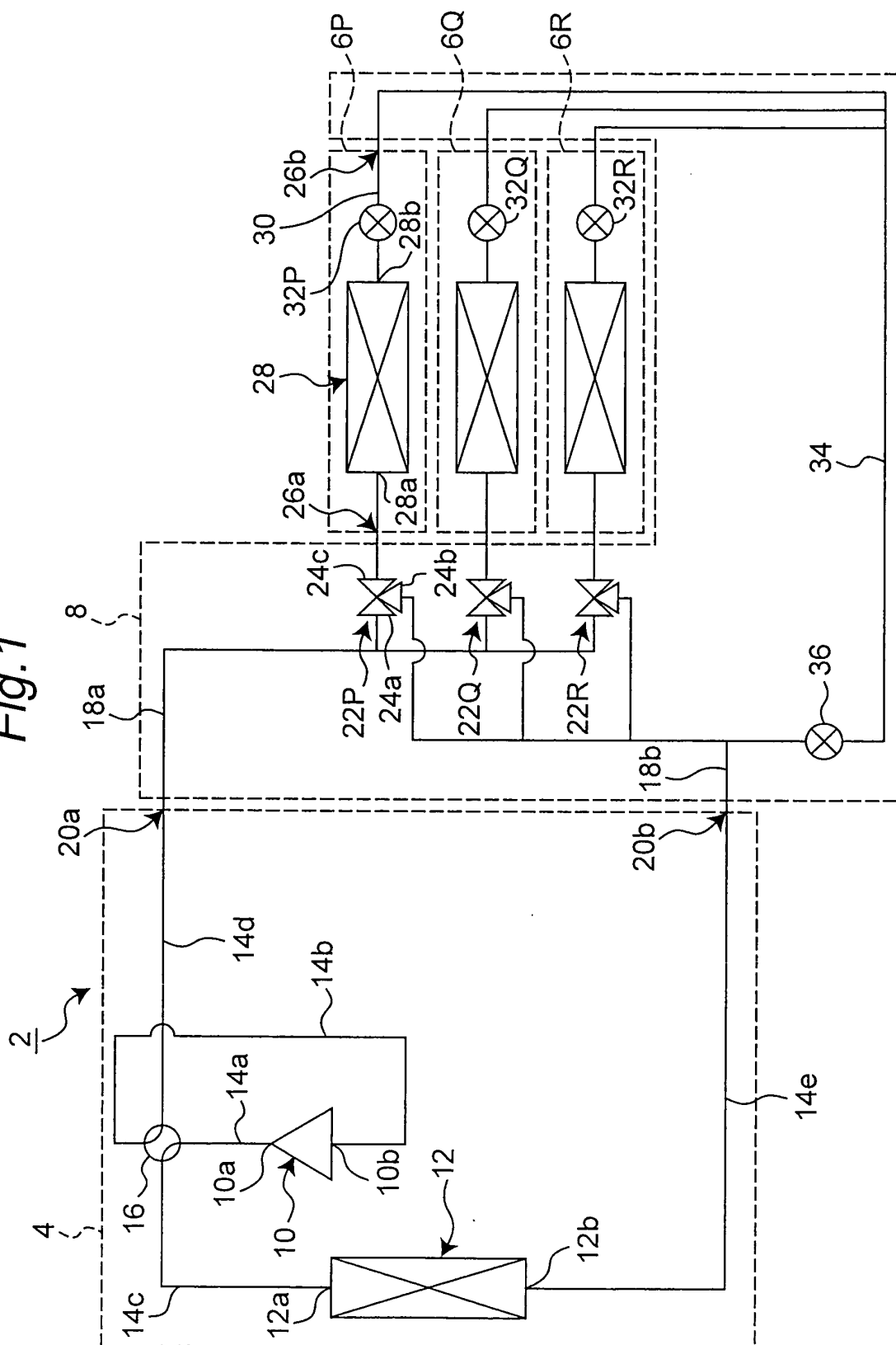


Fig.2

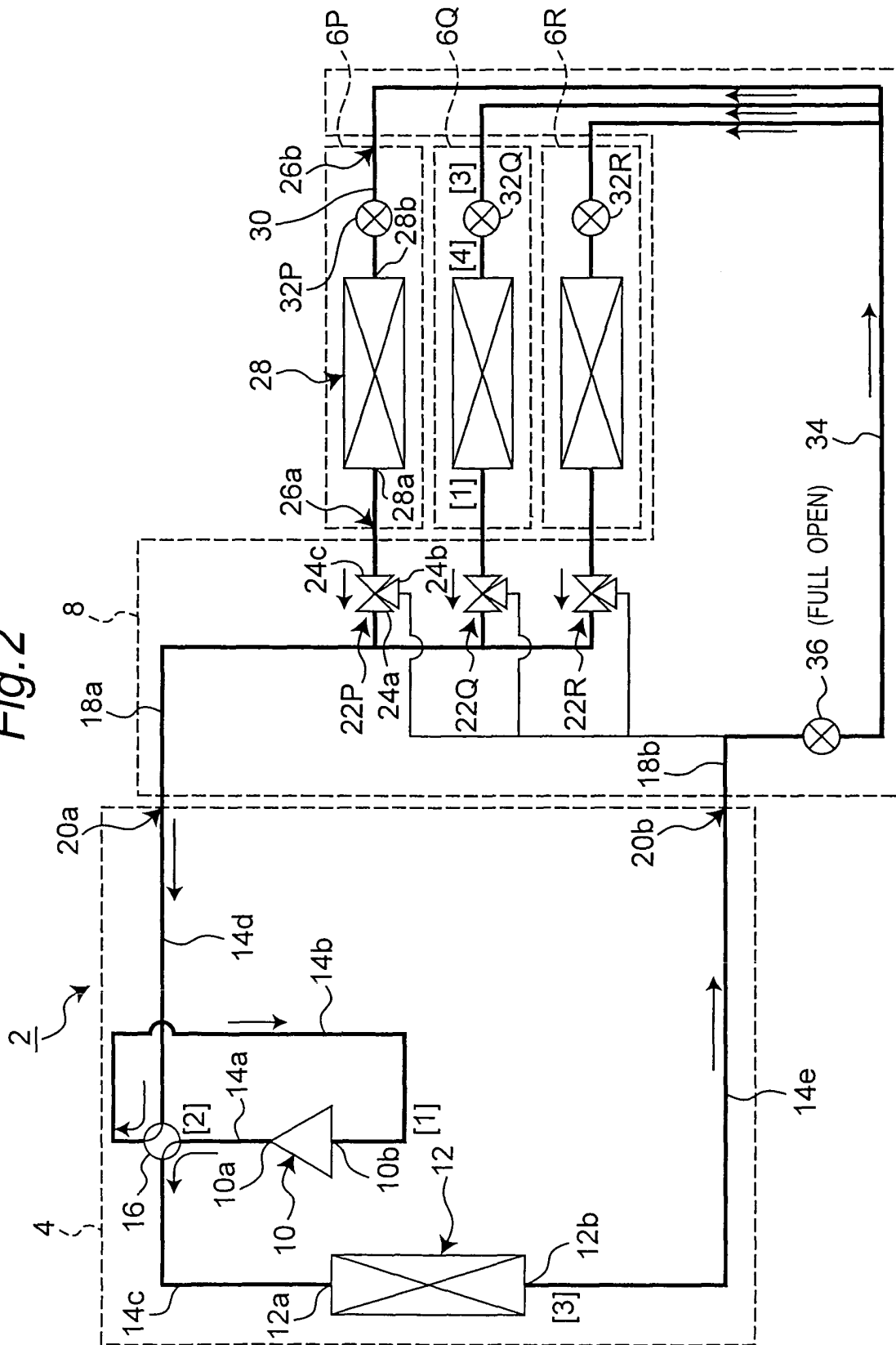


Fig.3

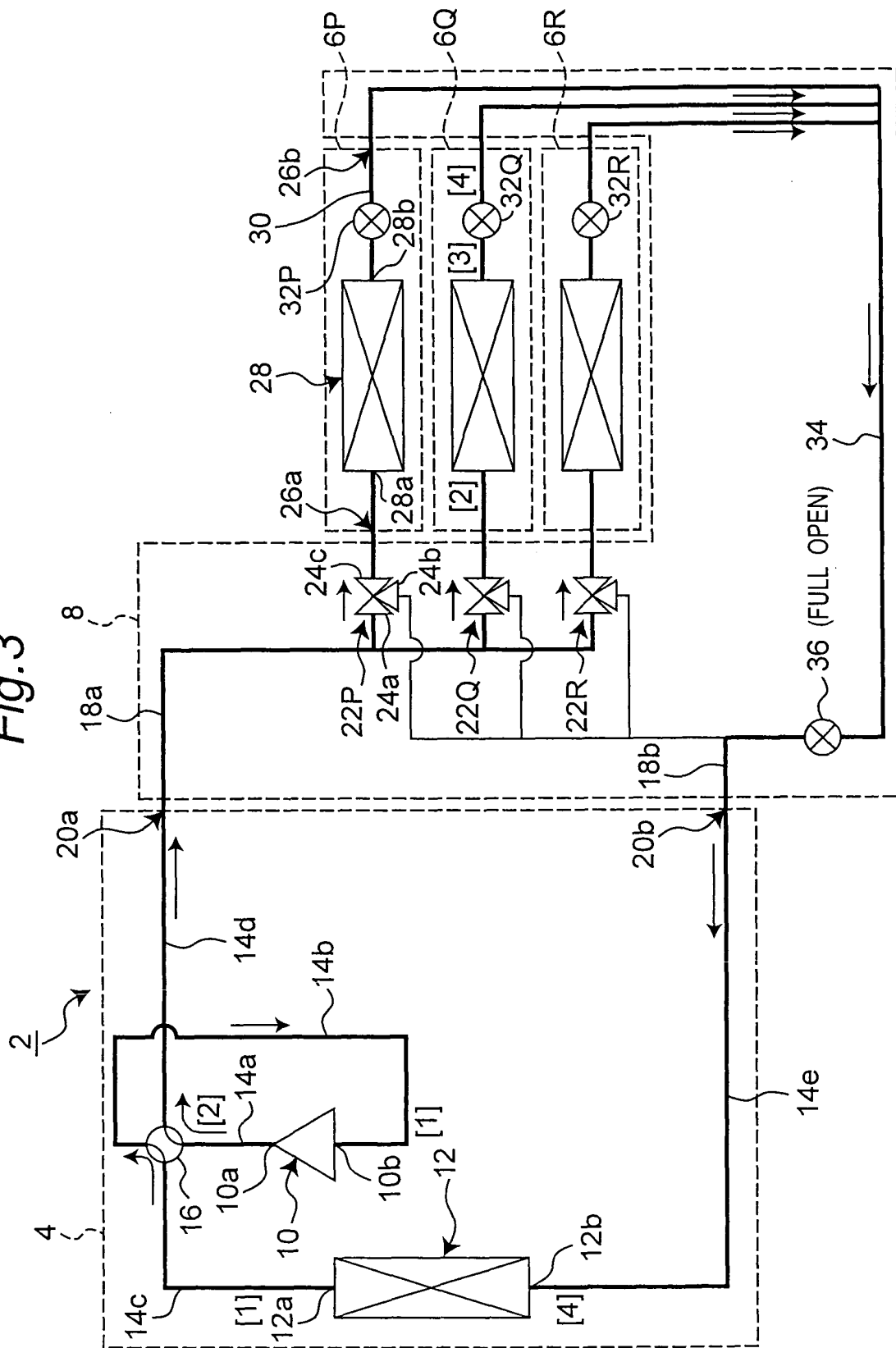


Fig.5

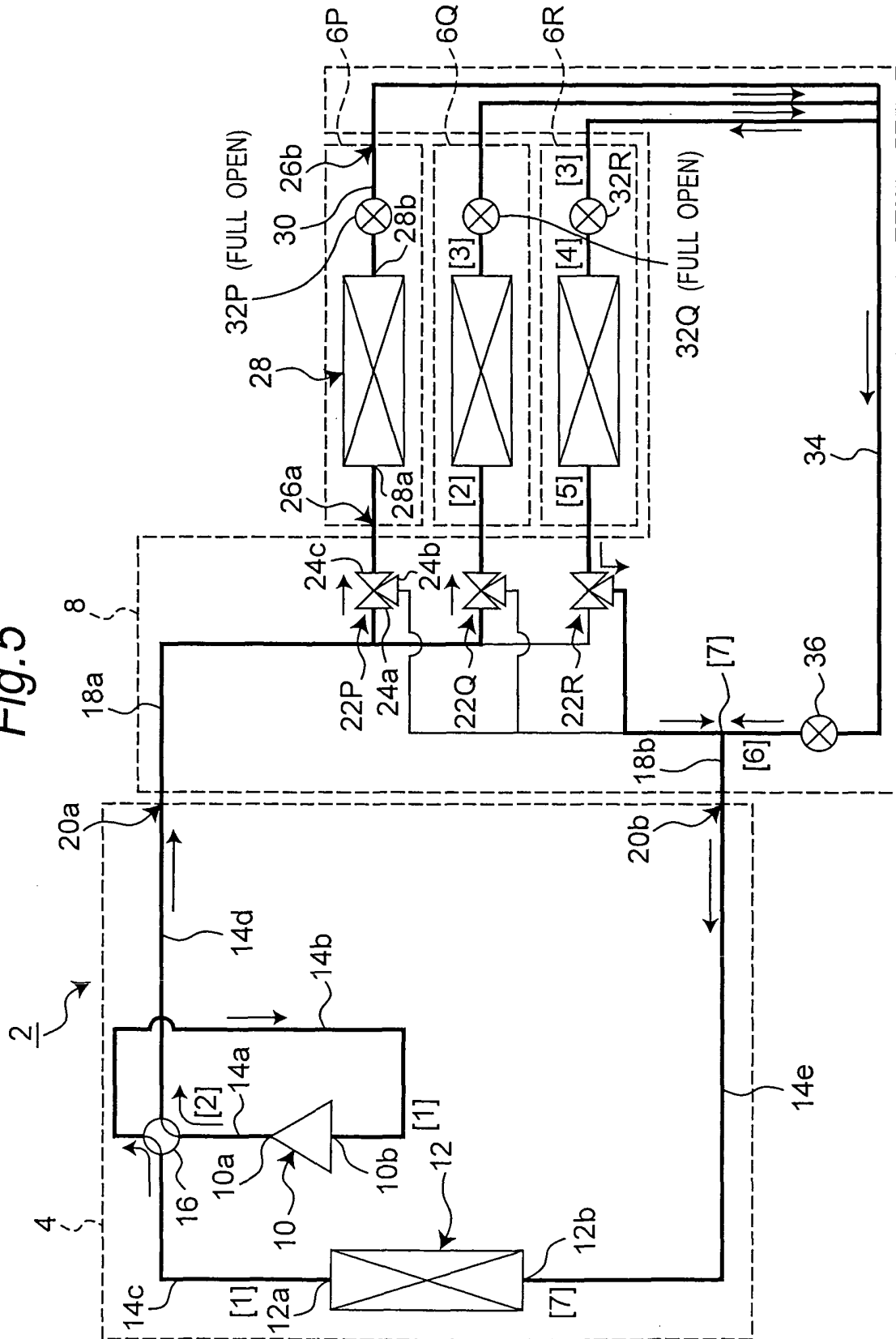
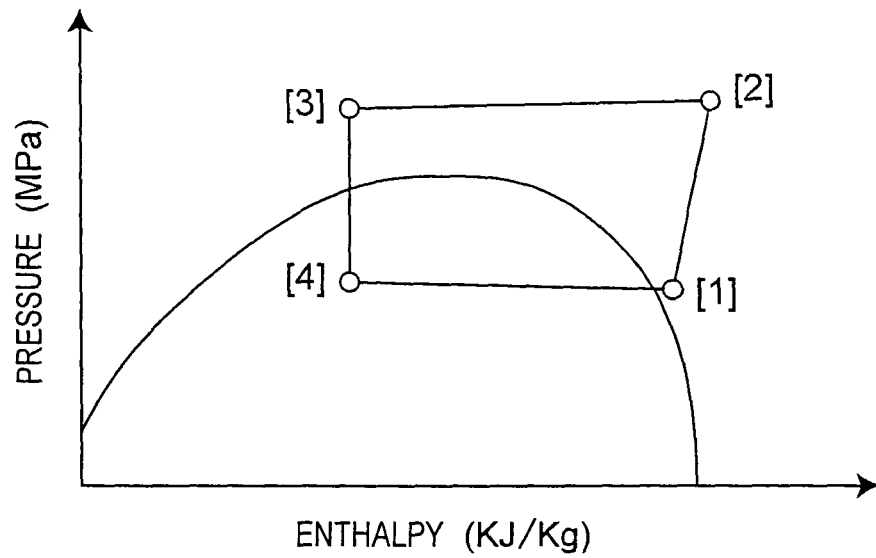


Fig.6

COOLING OPERATION MODE

*Fig.7*

HEATING OPERATION MODE

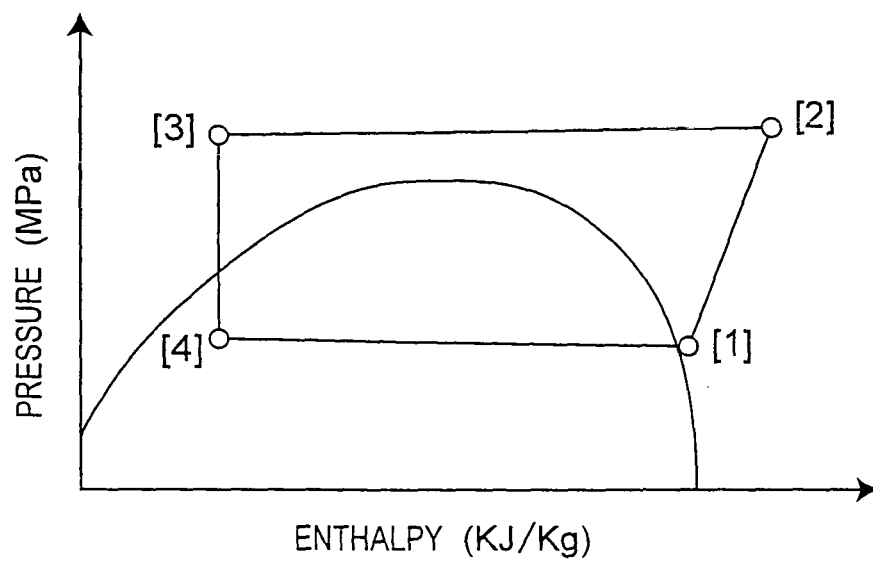
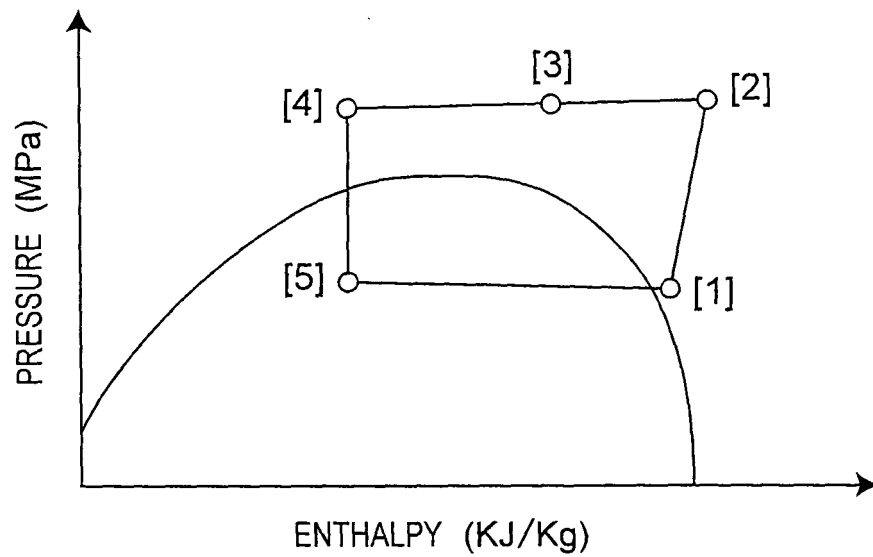


Fig.8

PRINCIPALLY COOLING OPERATION MODE

*Fig.9*

PRINCIPALLY HEATING OPERATION MODE

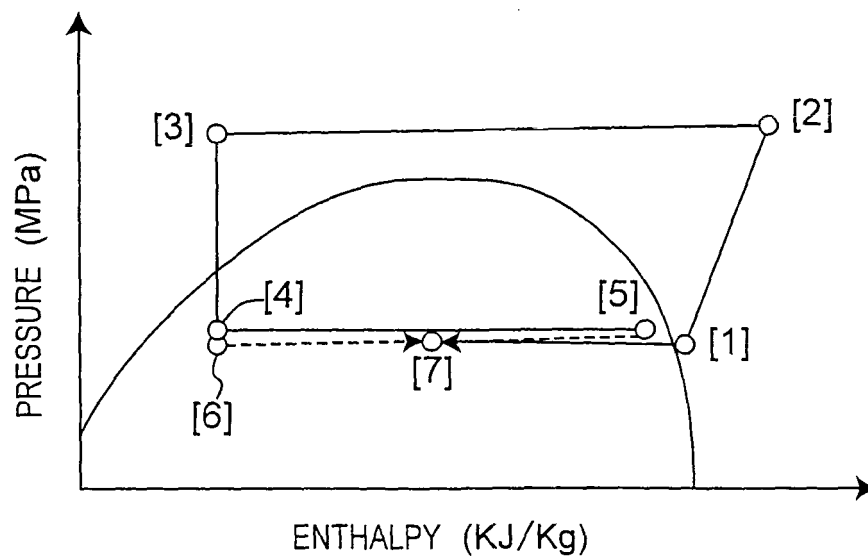


Fig. 10

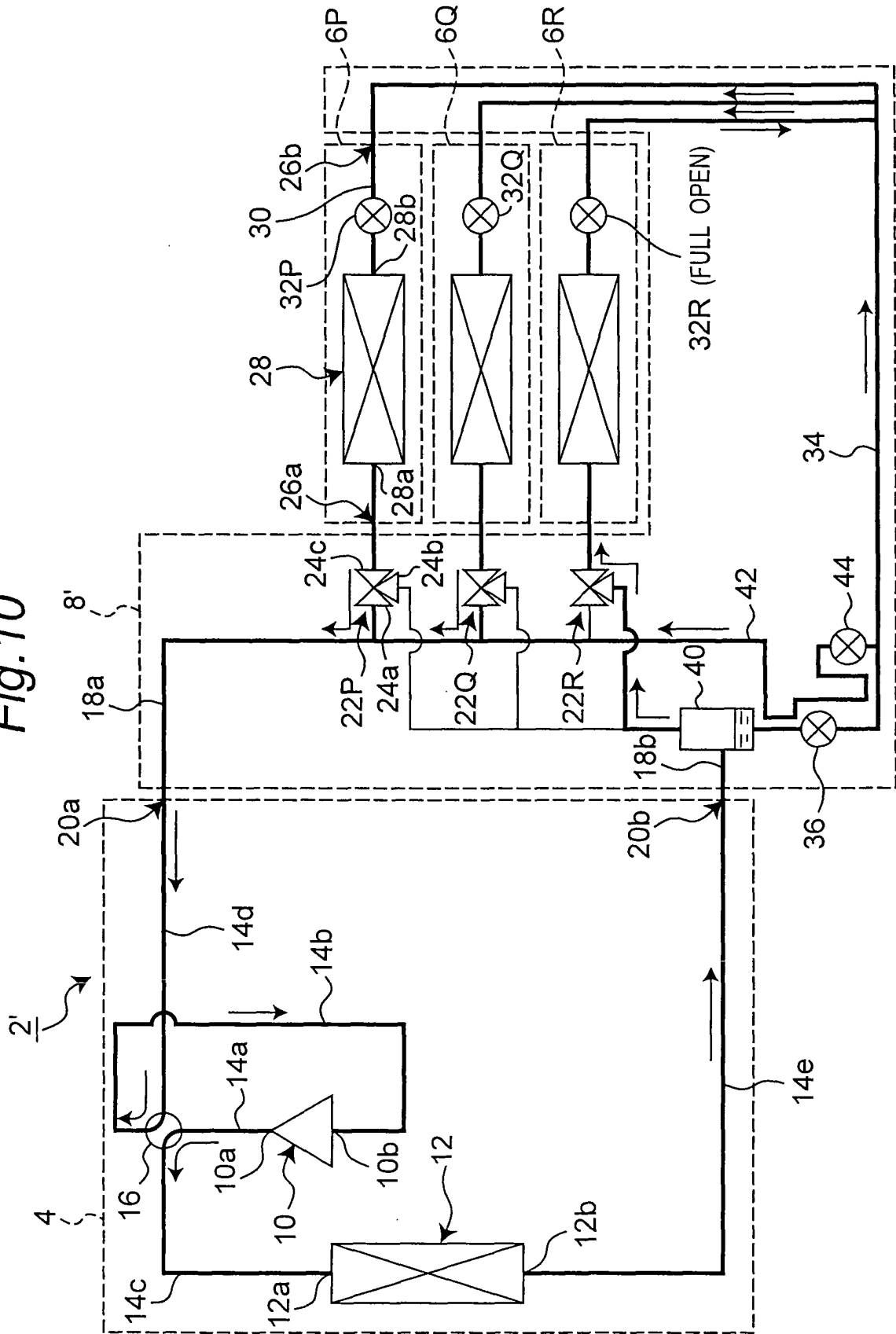


Fig. 11

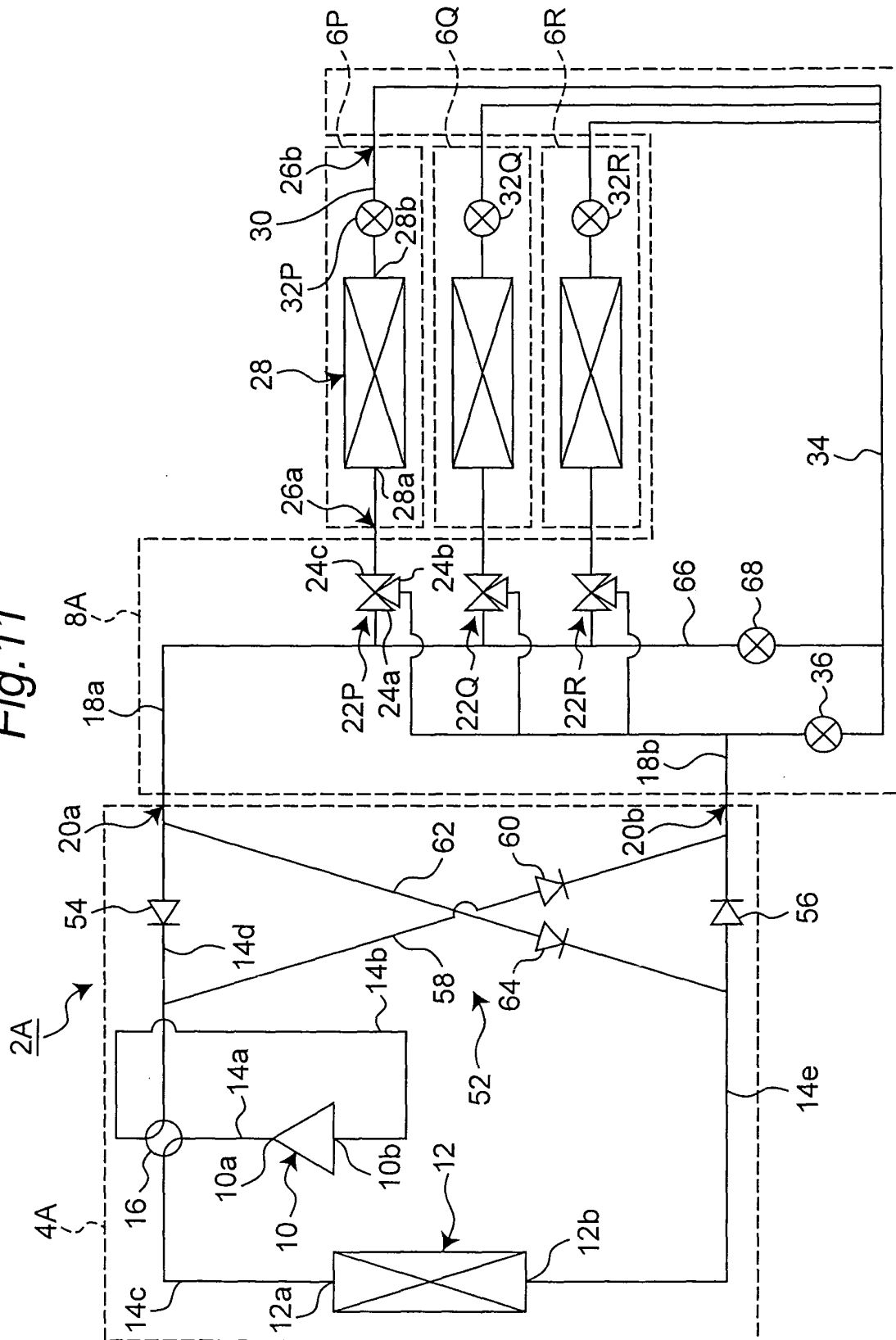
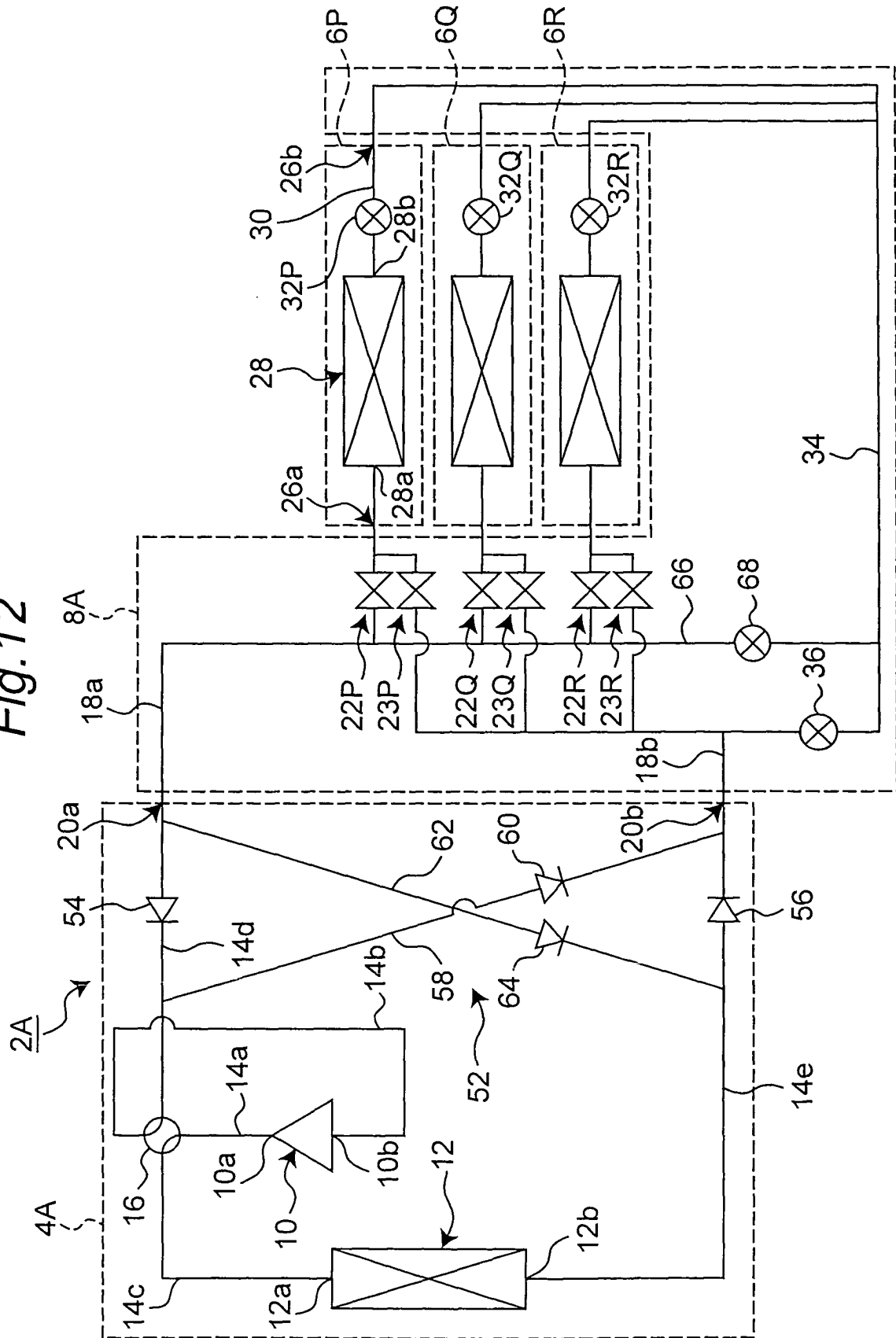


Fig. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/020109

A. CLASSIFICATION OF SUBJECT MATTER

F25B29/00 (2006.01), **F25B1/00** (2006.01), **F25B13/00** (2006.01)

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)

F25B29/00 (2006.01), **F25B1/00** (2006.01), **F25B13/00** (2006.01)

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	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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	JP 2522371 B2 (Mitsubishi Electric Corp.), 07 August, 1996 (07.08.96), Full text; Figs. 1 to 11 & US 4987747 A & EP 0364834 A2	1-3, 7-10 4-6
Y	JP 4-217759 A (Matsushita Refrigeration Co.), 07 August, 1992 (07.08.92), Pages 3, 4; Figs. 1 to 3 (Family: none)	4-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search
06 February, 2006 (06.02.06)Date of mailing of the international search report
14 February, 2006 (14.02.06)Name and mailing address of the ISA/
Japanese Patent Office

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Patent documents cited in the description

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