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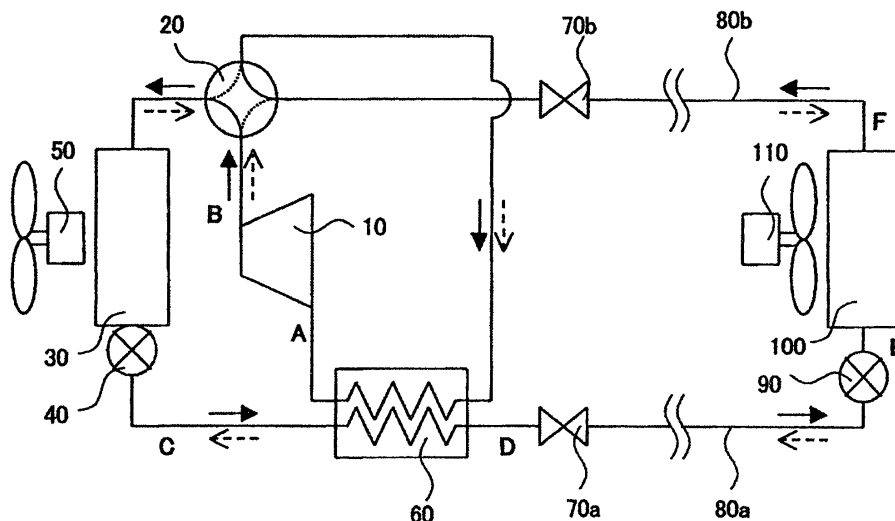
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(54) **Refrigeration cycle and water heater**

(57) In order to regulate discharge pressure in a refrigeration cycle without using a tank for regulating a refrigerant, there is provided a refrigeration cycle in which a compressor (10), a condenser (30), a variable pressure reducer (90) and an evaporator (100) are connected in sequence by a refrigerant pipe, wherein an internal heat exchanger (60) which causes heat exchange between a refrigerant which exits from the condenser or a gas cooler

(30,200) and a refrigerant which is sucked into the compressor is provided, and the discharge pressure is regulated by changing the refrigerant amount stored in the evaporator by regulating the pressure reduction amount of the variable pressure reducer. Also, it is preferable that the pressure reduction amount of the variable pressure reducer is decreased when the discharge pressure becomes a predetermined pressure or more.

**FIG.1**



## Description

**[0001]** The present invention relates to improvement in reliability and performance of a refrigeration cycle and a water heater.

**[0002]** From the viewpoint of protection of the ozone layer in recent years, a refrigeration cycle using a natural refrigerant such as a CO<sub>2</sub> refrigerant, of which ozone depletion potential is zero and of which global warming potential is much smaller as compared with chlorofluorocarbons attracts attention in recent years. The CO<sub>2</sub> refrigerant is characterized by constituting a trans-critical cycle in which a high pressure part exceeds a critical pressure, the pressure is defined by the temperature of a medium which exchanges heat with a gas cooler and by the refrigerant amount in the cycle, and particularly, it has the characteristic that the influence of the refrigerant amount is large as compared with a chlorofluorocarbon refrigerant. It is schematically shown in Fig. 4. In the case of CO<sub>2</sub>, since the outlet temperature of the gas cooler is under the control of the temperature of the heat exchange medium on the gas cooler side, when the temperature of the heat exchange medium is low, it is assumed that the state is as shown by the broken line in the drawing. If the temperature of the heat exchange medium on the gas cooler side rises in this refrigeration cycle, the gas cooler outlet density reduces in connection with rise in the gas cooler outlet temperature, and accordingly, the refrigeration cycle is shifted to the high pressure side having higher density for regulating the refrigerant retained amount. The solid line in Fig. 4 shows this state. If the pressure becomes too high, not only the reliability reduces, but also the performance reduces due to an improper refrigeration cycle. Therefore, it is generally conceived to provide a tank for regulating the refrigerant amount in the cycle to regulate the pressure properly. As an example of this, the one disclosed in JP-A-1-509515 is known.

**[0003]** In the above described prior art, since it is necessary to have a tank additionally, there has been the problem that it is impossible to simplify the refrigeration cycle.

**[0004]** A preferred aim of the present invention is to provide a refrigeration cycle with high reliability, which can regulate the high pressure of the discharge pressure without using a tank for regulating a refrigerant.

**[0005]** In one aspect of the present invention, a refrigeration cycle in which a compressor, a condenser, a variable pressure reducer and an evaporator are connected in sequence via a refrigerant pipe is configured to include an internal heat exchanger which causes a refrigerant which exits from the condenser and a refrigerant which is sucked into the compressor to exchange heat with each other, to detect the pressure of the refrigerant discharged from the compressor, and to change the refrigerant amount stored in the evaporator by regulating the pressure reduction amount of the variable pressure reducer in accordance with the detected pressure of the refriger-

ant.

**[0006]** Further, in the above aspect, it is preferable to reduce the pressure reduction amount of the variable pressure reducer when the discharge pressure becomes a predetermined pressure or more.

**[0007]** Further, in the above aspect, it is preferable to include a switching mechanism which switches the refrigerant exiting from the condenser to a passage which does not pass through the internal heat exchanger.

**[0008]** Further, in the above aspect, it is preferable to have a function of continuously regulating the amount of a refrigerant which passes through the internal heat exchanger and the amount of a refrigerant which does not pass through the internal heat exchanger, among the refrigerants exiting from the condenser.

**[0009]** Further, in the above aspect, it is preferable that the internal heat exchanger is connected to a check valve, and that the direction of the refrigerant flowing in the internal heat exchanger at the time of cooling is the same direction as the direction of the refrigerant flowing in the internal heat exchanger at the time of heating.

**[0010]** Further, in the above aspect, it is preferable that the refrigerant is a CO<sub>2</sub> refrigerant.

**[0011]** According to the present invention, it is possible to provide a refrigeration cycle having high reliability without using a tank for regulating a refrigerant.

**[0012]** Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

## IN THE DRAWINGS

**[0013]**

Fig. 1 is a block diagram of a refrigeration cycle showing a first embodiment of the present invention;  
 Fig. 2 is a p-h diagram of the refrigeration cycle;  
 Fig. 3 is a p-h diagram of the refrigeration cycle after a refrigerant moves;  
 Fig. 4 is a p-h diagram of the refrigeration cycle with respect to the temperature change of a gas cooler heat exchange medium;  
 Fig. 5 shows the relation between the quality and the void fraction on a low temperature side;  
 Fig. 6 shows the relation of the quality and the refrigerant retained amount on the low temperature side;  
 Fig. 7 is a block diagram of a heat pump type water heater showing a second embodiment of the present invention;  
 Fig. 8 is a block diagram of a heat pump type water heater showing a third embodiment of the present invention; and  
 Fig. 9 is a block diagram of a heat pump type water heater showing a fourth embodiment of the present invention.

**[0014]** Fig. 1 is a block diagram showing a refrigeration cycle of a first embodiment. A refrigerant is CO<sub>2</sub>, and the arrows of the solid line in the drawing show the flow of the refrigerant at the time of cooling. The high-temperature and high-pressure refrigerant from a compressor 10 passes through a four-way valve 20, emit heat to air at an outdoor heat exchanger 30 which works as a gas cooler by a blower 50, passes through a variable pressure reducer 40 which is reduced in pressure reduction amount to the limit, and is further cooled at an internal heat exchanger 60. The refrigerant passes through a stop valve 70a and a connection pipe 80a, is decreased in pressure by a variable pressure reducer 90, and deprives air of heat at an indoor heat exchanger 100 which works as an evaporator by a blower 110. Then, the refrigerant passes through a connection pipe 80b and a stop valve 70b, passes the four-way valve 20 again, is heated in the internal heat exchanger 60, and is sucked into the compressor 10 again. The p-h diagram of this refrigeration cycle is as shown by the solid line in Fig. 2. The characters A to F in the diagram designate the same positions in Fig. 1, and the heat exchanges of C to D and F to A are established in the internal heat exchanger. When the internal heat exchanger is not available, the refrigeration cycle is as shown by the broken line in the diagram. In the cycle of the solid line, the evaporator changes from a point E in the vicinity of a quality of 0.2 to a point F in the vicinity of a quality of 1.0. The diagram in which the pressure reduction amount of the variable pressure reducer 90 is decreased in this refrigeration cycle is shown in Fig. 3. By reducing the pressure reduction amount, the superheat amount of the compressor 10 can be reduced, and its heat exchange amount increases at the same time because the low temperature side of the internal heat exchanger 60 fully becomes low to be a saturation temperature. In this case, the evaporator changes from the quality in the vicinity of 0.1 to the quality in the vicinity of 0.65. The refrigerant retained amounts of both of these evaporators are considered. Fig. 5 shows the general relation between the quality and the void fraction in the saturation region at the low pressure side, and Fig. 6 shows the relation between the quality and the refrigerant retained amount per evaporator unit volume in view of the void fraction. The evaporator in Fig. 2 changes in quality from 0.2 to 1.0, and therefore, when averaging through the entire region, the refrigerant retained amount per evaporator unit volume is 350 kg/m<sup>3</sup>. On the other hand, in the refrigeration cycle in Fig. 3, the quality is from 0.1 to 0.65, and therefore, the refrigerant retained amount per evaporator unit volume is 460 kg/m<sup>3</sup>. That is, the same effect as the case of reducing the refrigerant by 110 kg/m<sup>3</sup> at the maximum per volume of the evaporator from the refrigeration cycle is obtained, and if the inner volume of the evaporator is properly designed, it is possible to move the refrigerant in the gas cooler and the refrigerant in the evaporator to each other by regulating the pressure reduction amount of the pressure reducer, which becomes a means for freely regulating high pres-

sure. Accordingly, excess and inadequacy of the high pressure are eliminated, and the refrigeration cycle can be operated in the state in which reliability and performance are improved. The above description is directed to operation at the time of cooling, and when the flow of the refrigerant is switched to the broken arrows by switching the four-way valve 20, heating operation is achieved. In this case, it is configured so that the pressure reduction amount of the variable pressure reducer 90 is decreased to the limit, and the pressure reduction is performed by the variable pressure reducer 40. In this configuration, when the discharge pressure is high, the pressure reduction amount is lowered (by making the opening degree large) to be regulated to obtain the target pressure. When the pressure is low on the contrary, the control to increase the discharge pressure is performed by increasing the pressure reduction amount (by making the opening degree small). In concrete, when the discharge pressure rises to a predetermined pressure or higher, the method of performing control to increase the pressure reduction amount or the like is conceivable.

**[0015]** Fig. 7 shows a second embodiment. The reference numerals and characters in the drawing are substantially the same as the first embodiment, but on-off valves 130a and 130b are added so that the internal heat exchanger 60 can be bypassed. When the on-off valve 130a is opened and the on-off valve 130b is closed, the refrigeration cycle is the same as that of the first embodiment. However, when the on-off valve 130a is closed and the on-off valve 130b is opened, the refrigeration cycle is in the state of the broken line of the p-h diagram in Fig. 3. In this case, the quality of the evaporator changes from 0.45 to 1.0, and the refrigerant retained amount per unit volume becomes 300 kg/m<sup>3</sup>. That is, in the refrigeration cycle of the broken line and the refrigeration cycle of the solid line in Fig. 3, it is possible to change the refrigerant amount stored in the evaporator from 300 kg/m<sup>3</sup> to 460 kg/m<sup>3</sup>, so that the refrigerant amount of 160 kg/m<sup>3</sup> can be regulated. By making the on-off valves 130a and 130b variable pressure reducers, the heat exchange amount of the internal heat exchanger 60 can be continuously changed, and the refrigerant retained amount can be continuously changed. In this embodiment, if the internal heat exchanger is not provided, a large amount of liquid refrigerant may flow into the compressor, which reduces reliability of the compressor. This is because the entrance of the compressor moves to F from A in Fig. 3. Owing to the internal heat exchanger, refrigerant quality at the entrance of the compressor can be enhanced even if the quality at the outlet of the evaporator is reduced in order to store the refrigerant in the evaporator.

**[0016]** Fig. 8 shows a block diagram of a refrigeration cycle of a third embodiment. The reference numerals and characters in the diagram are substantially the same as the first embodiment, but four of the check valves 120 are added. In the first embodiment, since the internal heat exchanger 60 is a parallel flow type internal heat

exchanger, the heat exchange amount reduces, but in this embodiment, the internal heat exchanger is of a counter flow type at the time of cooling as well as heating, so that the configuration is possible only by one pressure reducer. The configuration including the circuit bypassing the gas cooler 60 can be enabled by using the on-off valves or the variable pressure reducers as in the second embodiment.

[0017] Fig. 9 is a fourth embodiment. The fourth embodiment is basically the same as the first embodiment, but a gas cooler 200 is configured to exchange heat with water, and is in the case of being used for a heat pump type water heater which flows low-temperature feed water 220a by a pump 210 to obtain high-temperature tapping 220b. If the temperature of the feed water 220a is high, the discharge pressure also rises in this case, and therefore, by moving the refrigerant to the evaporator 30 by regulating the variable pressure reducer 40, the discharge pressure can be regulated to a proper discharge pressure.

[0018] The above embodiments are described with respect to the case that the refrigerant is CO<sub>2</sub>, but can be also applied to a chlorofluorocarbon refrigerant and an HC refrigerant which operate at a critical point pressure or less.

[0019] It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims, as interpreted by the description and drawings.

## Claims

1. A refrigeration cycle in which a compressor, a condenser, a variable pressure reducer and an evaporator are connected in sequence by a refrigerant pipe, **characterized in that** the refrigeration cycle comprises an internal heat exchanger which causes heat exchange between a refrigerant which exits from the condenser and a refrigerant which is sucked into the compressor, and the refrigerant amount stored in the evaporator is changed by detecting pressure of the refrigerant discharged from the compressor and by regulating the pressure reduction amount of the variable pressure reducer in accordance with the detected pressure of the refrigerant.
2. The refrigerant cycle according to claim 1, **characterized in that** the pressure reduction amount of the variable pressure reducer is decreased when the detected pressure of the refrigerant discharged from the compressor becomes a predetermined pressure or more.
3. The refrigeration cycle according to claim 1, **characterized by** comprising a switching mechanism which switches the refrigerant exiting from the condenser to a passage which does not pass through the internal heat exchanger.
4. The refrigeration cycle according to claim 2, **characterized by** having a function of continuously regulating the amount of a refrigerant which passes through the internal heat exchanger and the amount of a refrigerant which does not pass through the internal heat exchanger, among the refrigerants exiting from the condenser.
5. The refrigeration cycle according to claim 1, **characterized in that** the internal heat exchanger is connected to a check valve, and a direction of the refrigerant flowing in the internal heat exchanger at the time of cooling is the same as a direction of the refrigerant flowing in the internal heat exchanger at the time of heating.
6. The refrigeration cycle according to claim 1, **characterized in that** the refrigerant is a CO<sub>2</sub> refrigerant.
7. A water heater comprising a refrigeration cycle in which a compressor, a condenser, a variable pressure reducer and an evaporator are connected in sequence by a refrigerant pipe, the condenser performing heat exchange with water, **characterized in that** the water heater comprises an internal heat exchanger which causes heat exchange between a refrigerant which exits from the condenser and a refrigerant which is sucked into the compressor, and the refrigerant amount stored in the evaporator is changed by detecting pressure of the refrigerant discharged from the compressor and by regulating the pressure reduction amount of the variable pressure reducer in accordance with the detected pressure of the refrigerant.
8. The water heater according to claim 7, **characterized in that** the pressure reduction amount of the variable pressure reducer is decreased when the detected pressure of the refrigerant discharged from the compressor becomes a predetermined pressure or more.
9. The water heater according to claim 7, **characterized by** comprising a switching mechanism which switches the refrigerant exiting from the condenser to a passage which does not pass through the internal heat exchanger.
10. The water heater according to claim 8, **characterized by** having a function of continuously regulating the amount of a refrigerant passing through the in-

ternal heat exchanger and the amount of a refrigerant which does not pass through the internal heat exchanger, among the refrigerants exiting from the condenser.

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11. The water heater according to claim 7, **characterized in that** the internal heat exchanger is connected to a check valve, and a direction of the refrigerant flowing in the internal heat exchanger at the time of cooling is the same as a direction of the refrigerant flowing in the internal heat exchanger at the time of heating.

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12. The water heater according to claim 7, **characterized in that** the refrigerant is a CO<sub>2</sub> refrigerant.

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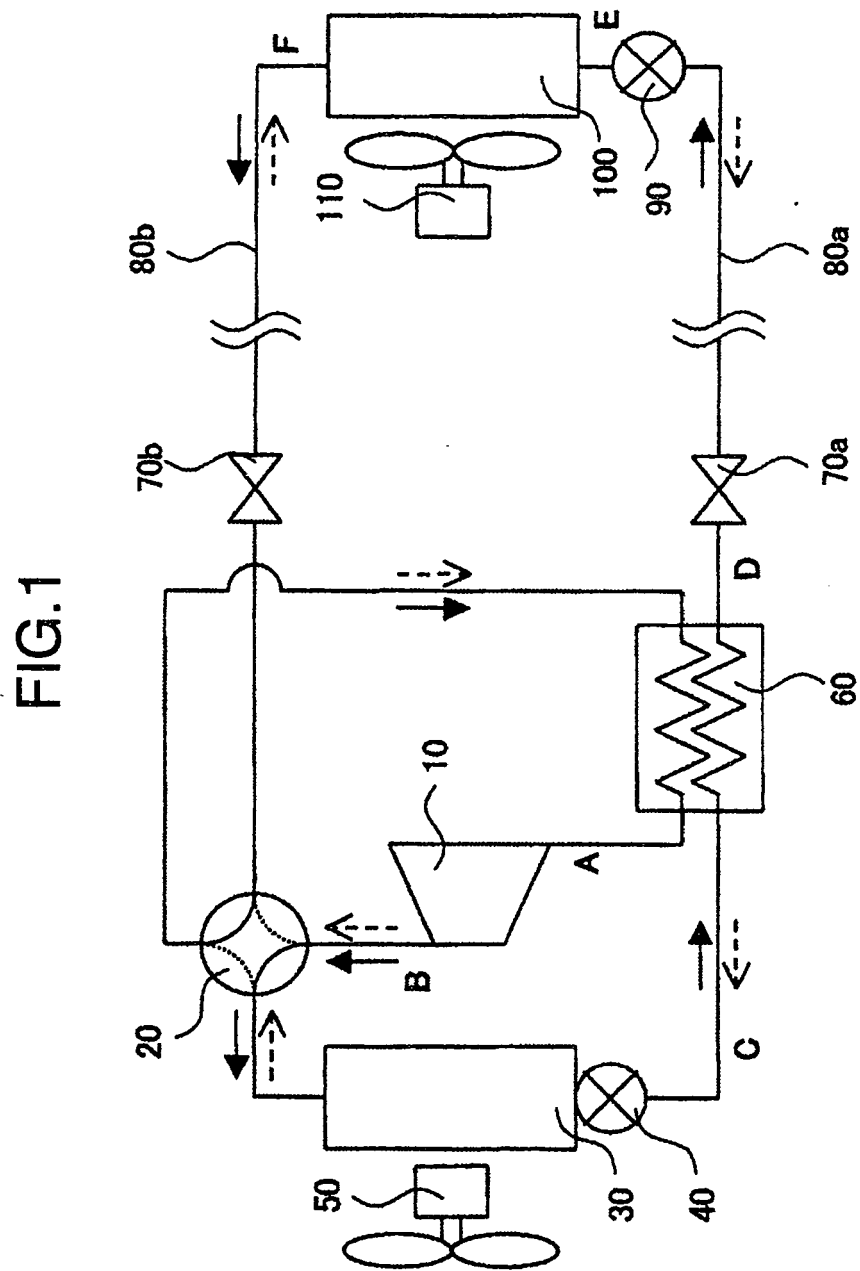


FIG.2

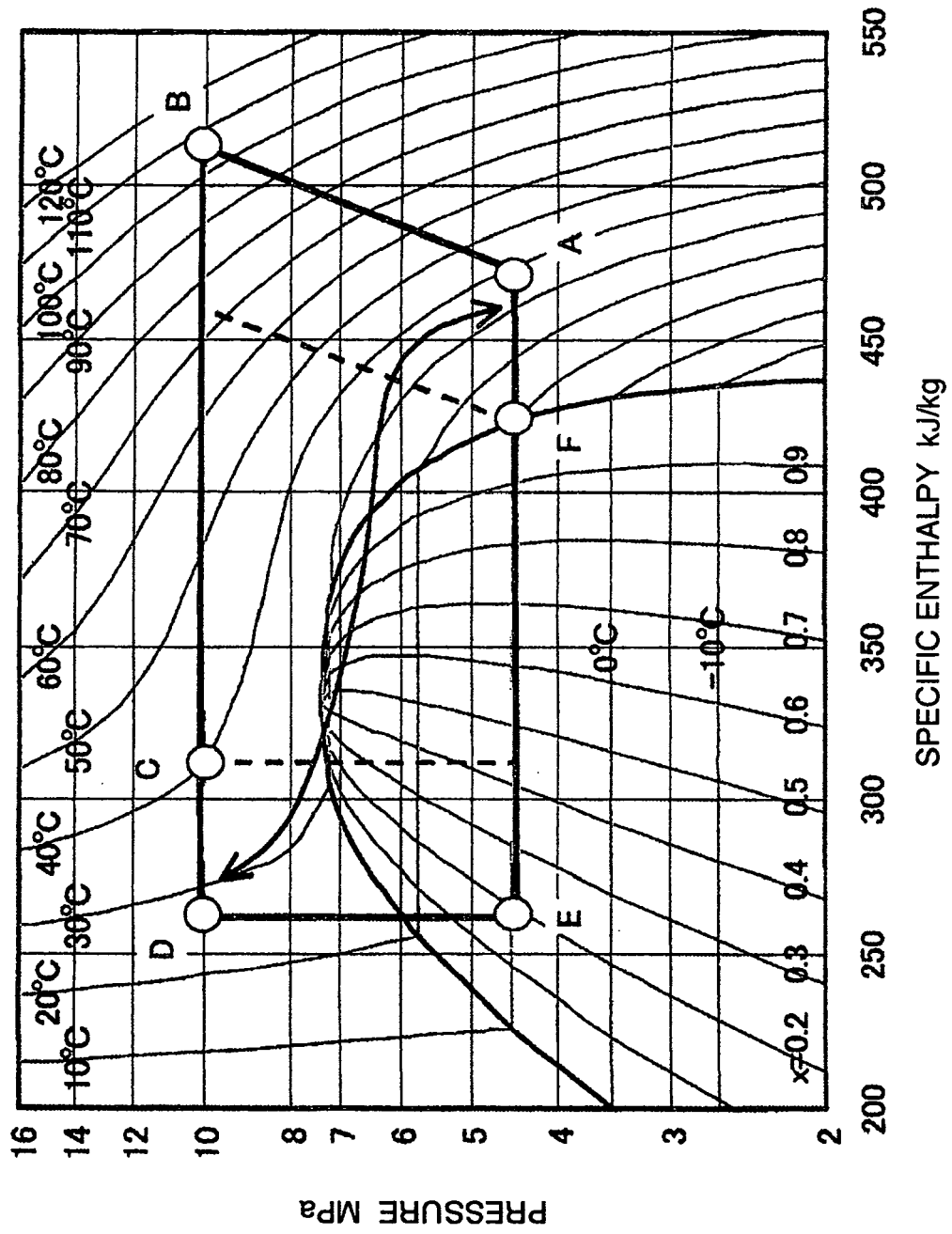


FIG.3

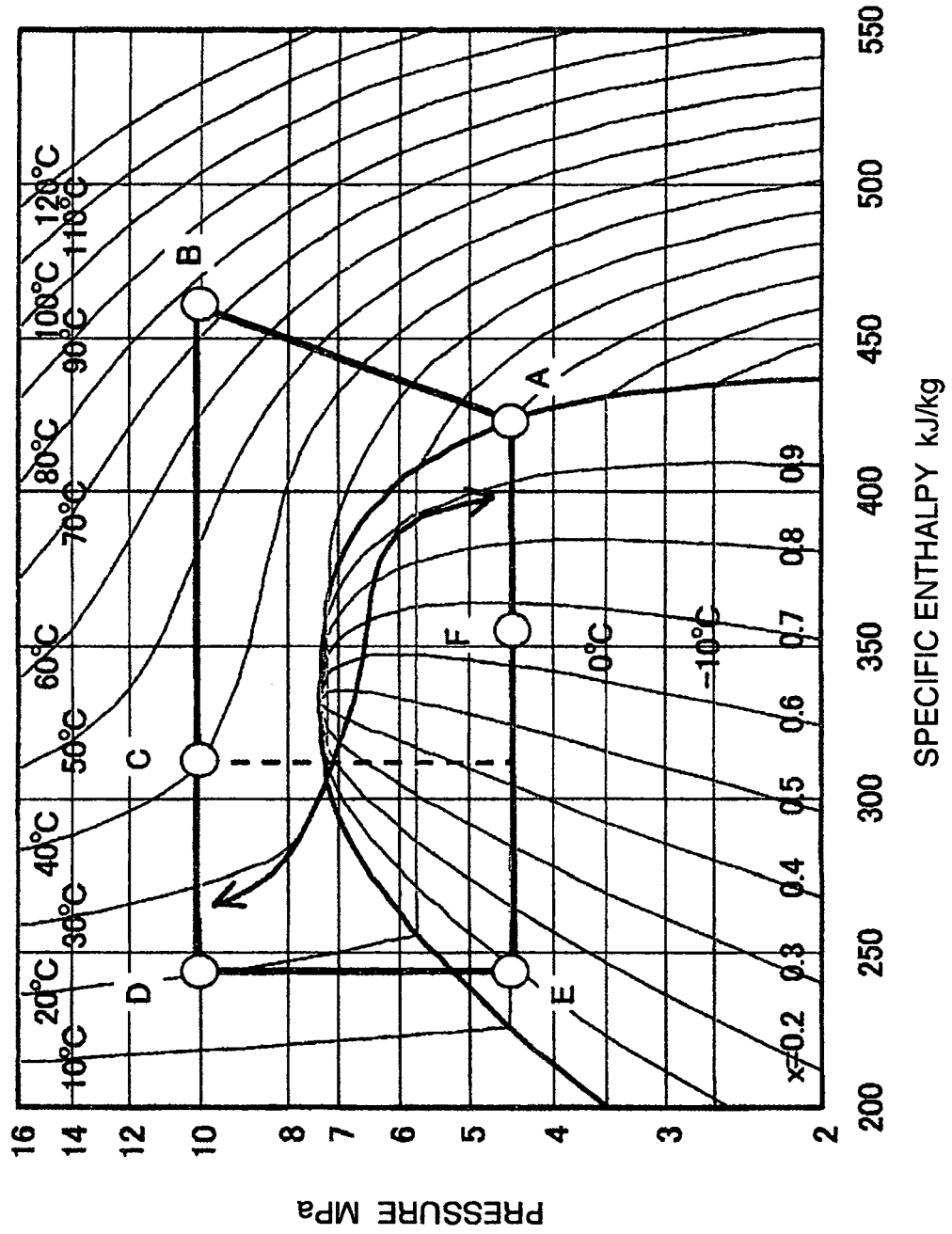


FIG.4

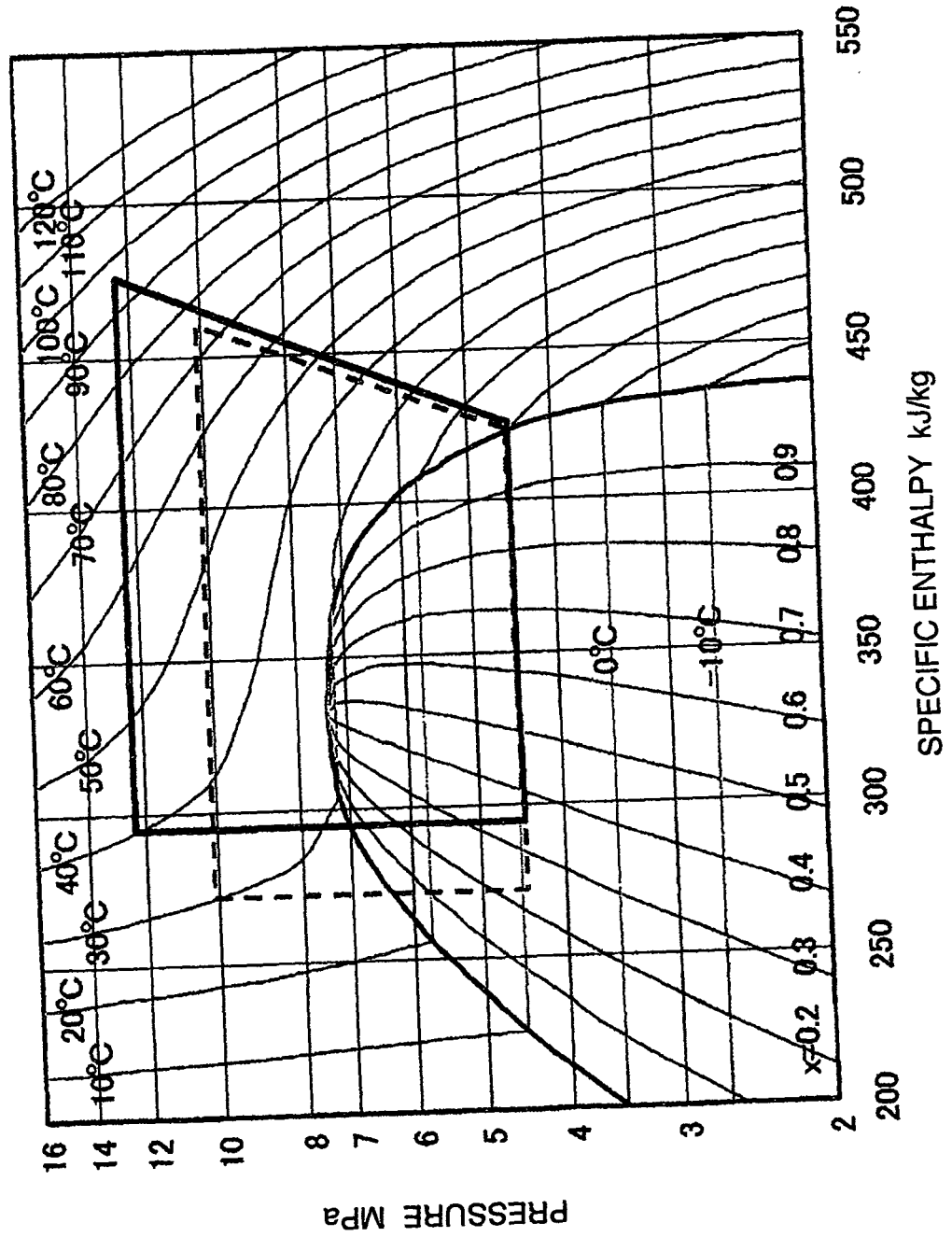


FIG.5

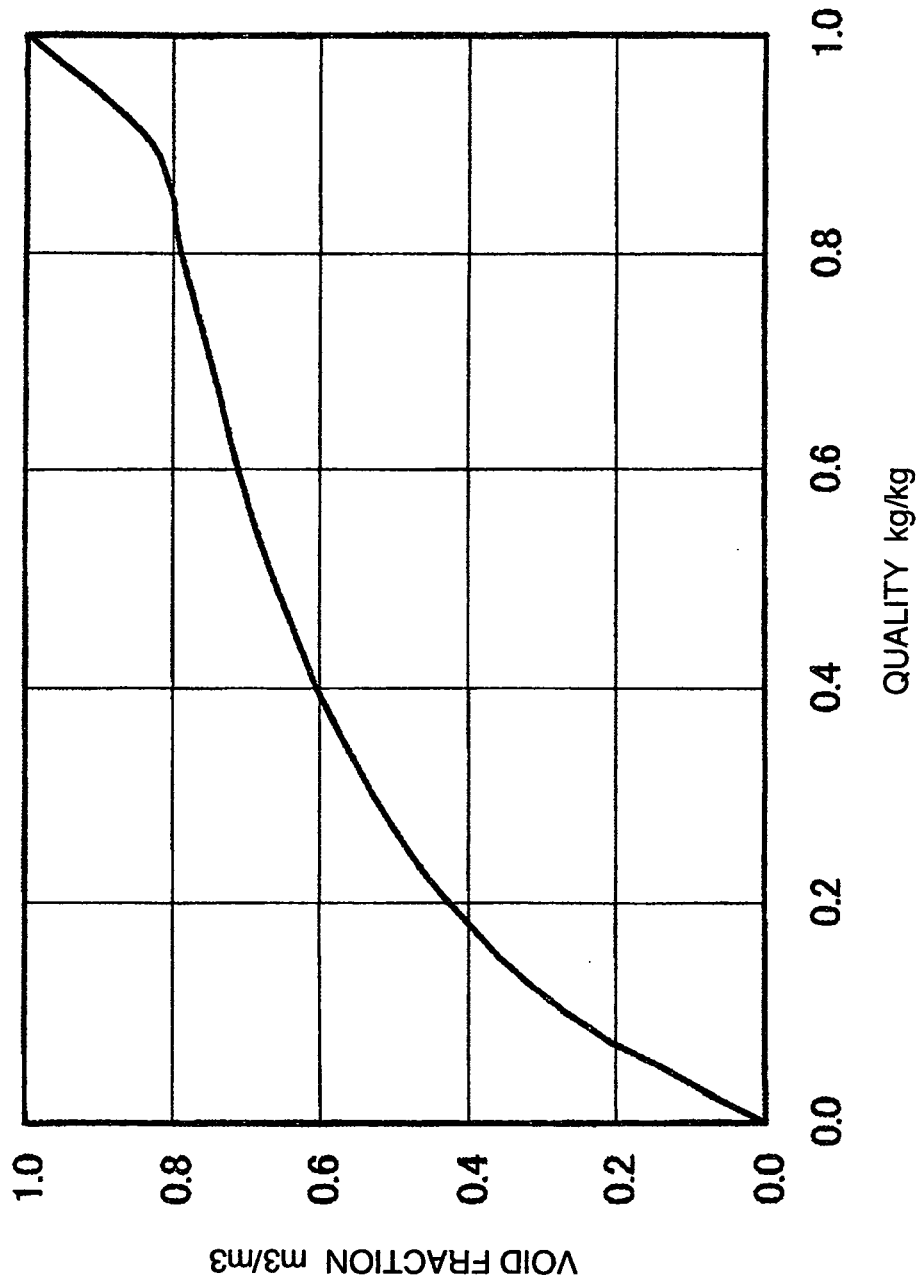


FIG.6

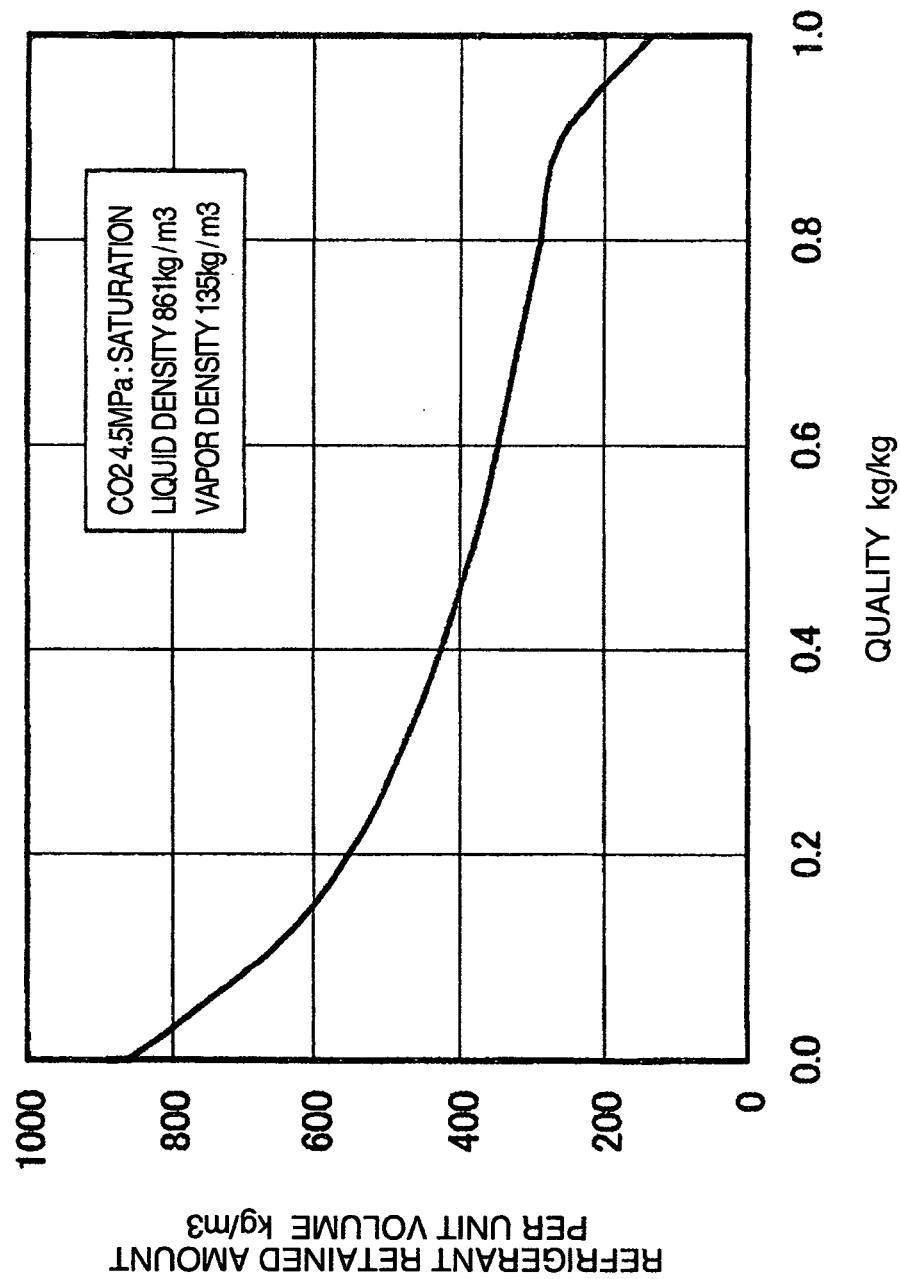


FIG.7

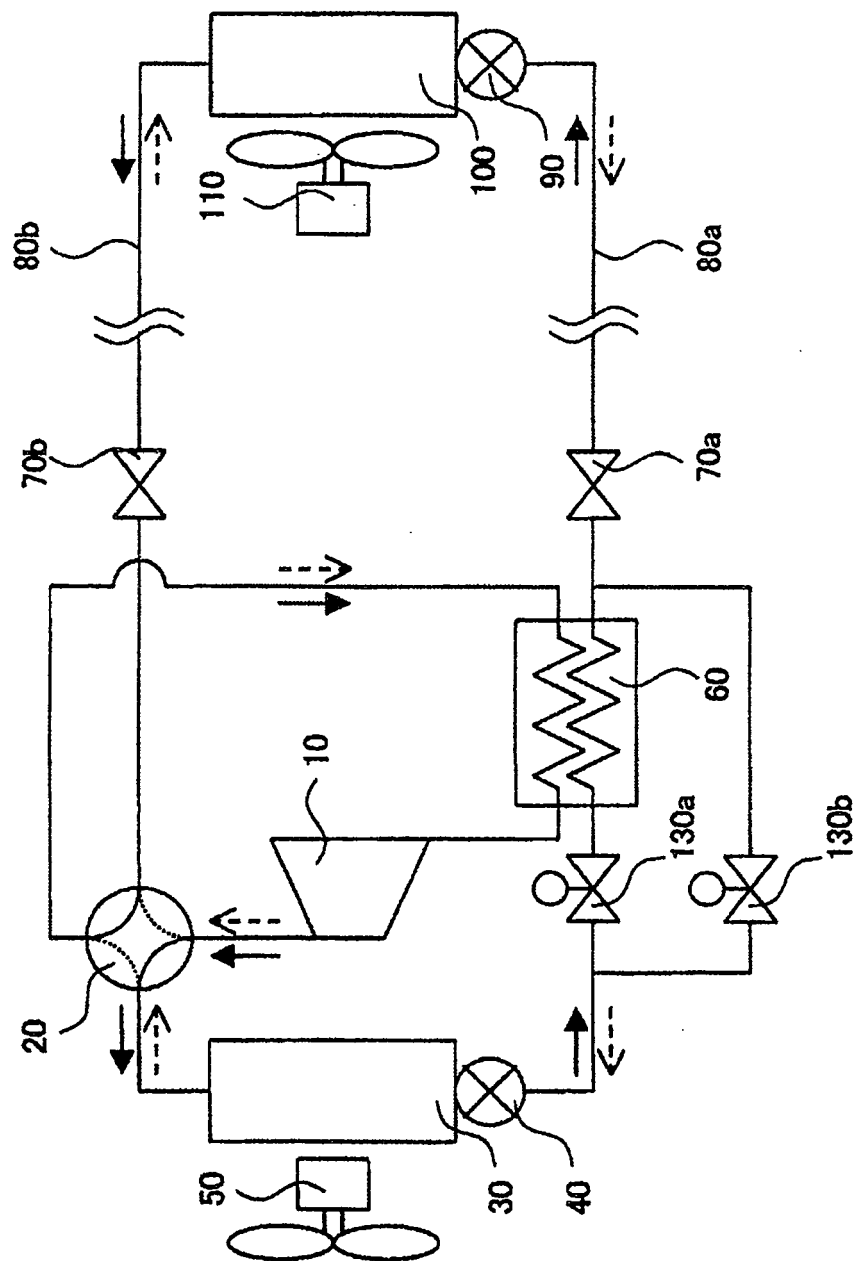


FIG.8

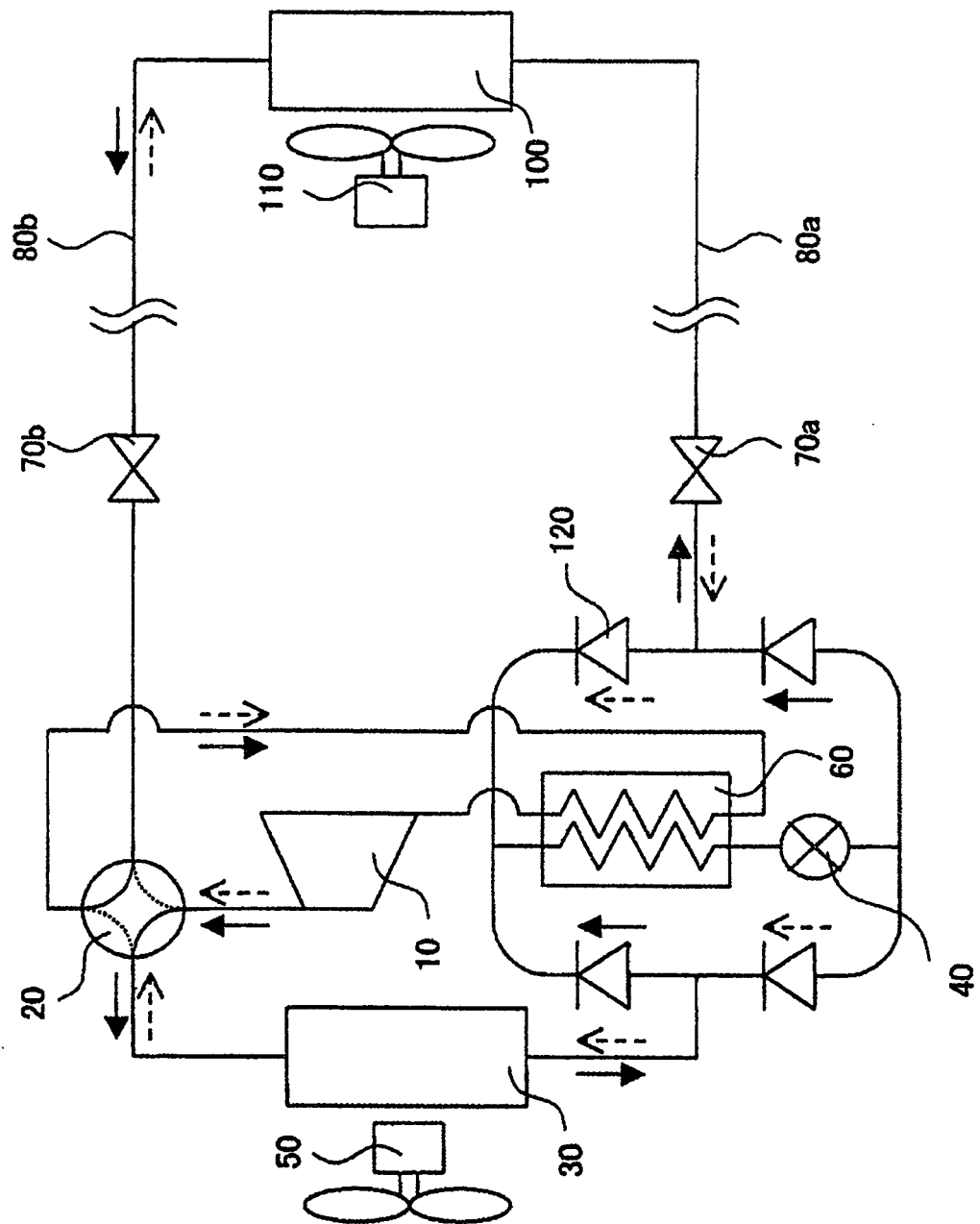
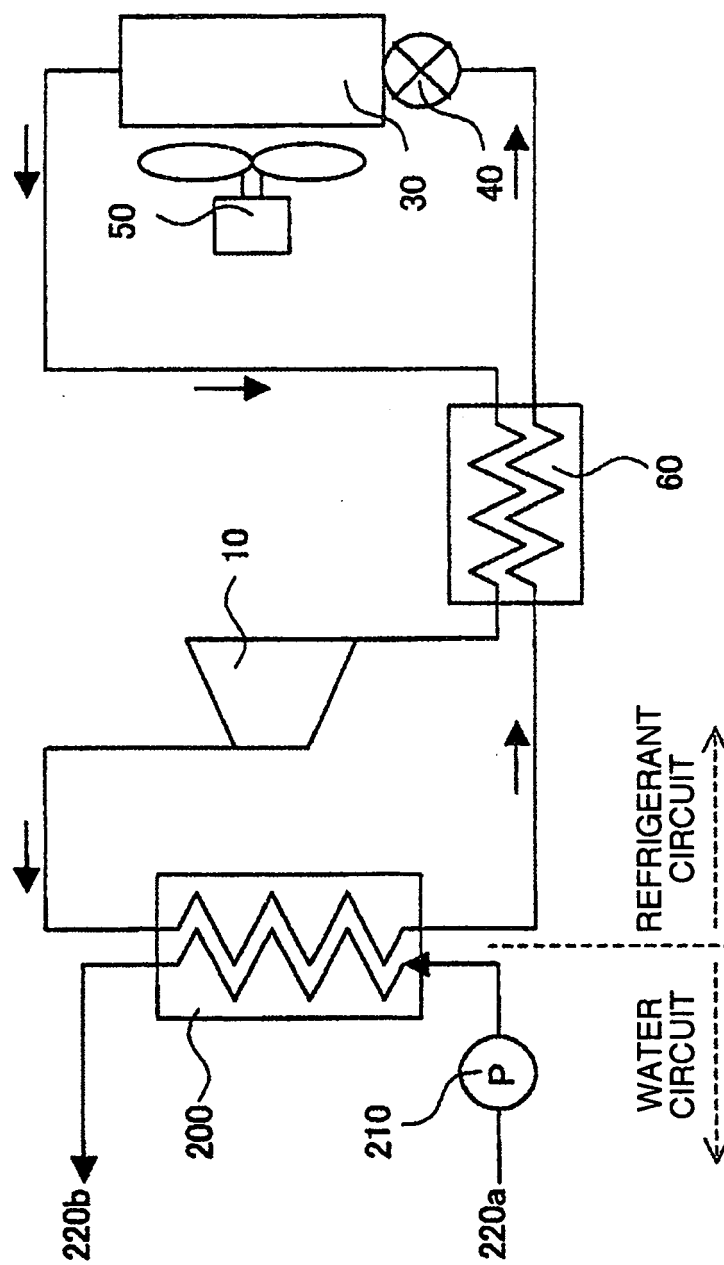


FIG. 9



**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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