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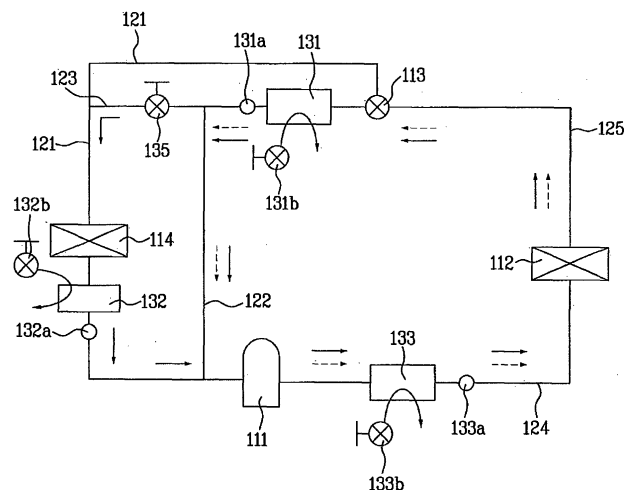
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(54) **Cooling/heating system and method for controlling the same**

(57) A cooling/heating system includes a compressor (111), an indoor heat exchanger (112), an expansion device (113), and an outdoor heat exchanger (114) which

are connected in series via a refrigerant line, wherein a refrigerant, which flows through the refrigerant line, heat-exchanges with supply water. A method for controlling the cooling/heating system is also disclosed.

**FIG. 1A**



## Description

**[0001]** The present invention relates to a cooling/heating system. It more particularly relates to a cooling/heating system wherein heating is carried out using hot water supplied from a district heating net, and a method for controlling the cooling/heating system.

**[0002]** Air conditioning systems generally perform procedures of compressing, condensing, expanding and evaporating a refrigerant to cool and/or heat a confined space.

**[0003]** Such air conditioning systems can be classified into a general type wherein one indoor unit is connected to one outdoor unit, and a multi-unit type wherein a plurality of indoor units are connected to one outdoor unit. Such air conditioning systems can also be classified into a cooling type wherein a refrigerant flows only in one direction through a refrigerant cycle, to supply cold air to a confined space, and a cooling and heating type wherein a refrigerant flows bi-directionally in a selective manner through a refrigerant cycle, to selectively supply cold air or hot air to a confined space.

**[0004]** Recent tendency of building construction is to densely construct large buildings in a wide area, as in apartment complexes. Also, such apartment complexes have been densely constructed in neighboring areas. In such a dense building area, hot water is supplied through a central supply system, in order to conserve energy and for the convenience of living. In such a dense building area, a district heating system using hot water is also mainly used to heat buildings.

**[0005]** In an area using the district heating system, each building therein must be equipped with both a heating system and a cooling system. For example, a system for cooling purposes alone, which uses refrigerant pipes, is installed in each building. Also, an indoor unit for heating purposes alone, which uses hot water pipes, is installed in each room of each building. In this arrangement, hot water from a district heating system is circulated through each indoor unit in heating mode. On the other hand, in cooling mode, each cooling system is operated.

**[0006]** However, the above-mentioned conventional cooling/heating system has the following problems.

**[0007]** First, since the conventional district cooling/heating system must be equipped with indoor units for heating purposes alone, in addition to the systems for cooling purposes alone, there are problems of double installation costs and an increase in maintenance and repair costs caused by the installation of both the cooling and heating systems.

**[0008]** Second, since compression of a refrigerant using compressors and circulation of the refrigerant are required in the above-mentioned general cooling/heating system, there is a problem of an increase in power consumption caused by an increase in the compression work of the compressors.

**[0009]** Third, in the above-mentioned general cooling/heating system, frost is formed on outdoor heat exchangers

in heating mode. In order to remove the frost, a defrosting operation is carried out in which a refrigerant is circulated in cooling mode. For this reason, there is a problem in that the heating operation cannot be continuously carried out.

The present invention seeks to provide improved heating/cooling systems and methods.

**[0010]** In accordance with a first aspect of the invention, a cooling/heating system comprises: a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, and means for exchanging heat between a refrigerant, which flows through the refrigerant line, and supply water.

**[0011]** The refrigerant line may comprise a first parallel line and a second parallel line which are arranged between the expansion device and the compressor. The outdoor heat exchanger may be arranged in the first parallel line.

**[0012]** The cooling/heating system may further comprise a first heat exchanger, through which the supply water passes, and which is arranged in the second parallel line. The first heat exchanger may heat-exchange with the refrigerant passing through the second parallel line, using the supply water.

**[0013]** The cooling/heating system may further comprise a second heat exchanger, through which the supply water passes, and which is arranged in the first parallel line between the outdoor heat exchanger and the compressor. The second heat exchanger may heat-exchange with the refrigerant passing through the first parallel line, using the supply water.

**[0014]** The cooling/heating system may further comprise a third heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the compressor and the indoor heat exchanger. The third heat exchanger may heat-exchange with the refrigerant passing through the refrigerant line between the compressor and the indoor heat exchanger, using the supply water.

**[0015]** The cooling/heating system may further comprise a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger.

**[0016]** The cooling/heating system may further comprise a fourth heat exchanger, through which the supply water passes, and which is arranged in the bypass line. The fourth heat exchanger may heat-exchange with the refrigerant passing through the bypass line, using the supply water.

**[0017]** The first through fourth heat exchangers may have independent supply water flow paths, respectively. Alternatively, at least two of the first through fourth heat exchangers may have a common supply water flow path.

**[0018]** The refrigerant line may comprise a first parallel line and a second parallel line which are arranged be-

tween the expansion device and the outdoor heat exchanger. The cooling/heating system may further comprise a first heat exchanger, through which the supply water passes, and which is arranged in the second parallel line. The first heat exchanger may heat-exchange with the refrigerant passing through the second parallel line, using the supply water.

**[0019]** The cooling/heating system may further comprise a valve arranged in the second parallel line to open/close a refrigerant flow path through the connecting line.

**[0020]** The cooling/heating system may further comprise a second heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the outdoor heat exchanger and the compressor. The second heat exchanger may heat-exchange with the refrigerant passing through the refrigerant line, using the supply water.

**[0021]** The cooling/heating system may further comprise a third heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the compressor and the indoor heat exchanger. The third heat exchanger may heat-exchange with the refrigerant passing through the refrigerant line between the compressor and the indoor heat exchanger, using the supply water.

**[0022]** The cooling/heating system may further comprise a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger.

**[0023]** The cooling/heating system may further comprise a fourth heat exchanger, through which the supply water passes, and which is arranged in the bypass line. The fourth heat exchanger may heat-exchange with the refrigerant passing through the bypass line, using the supply water.

**[0024]** The cooling/heating system may further comprise a temperature sensor arranged at a refrigerant outlet side of at least one of the first through fourth heat exchangers.

**[0025]** The first through fourth heat exchangers may have independent supply water flow paths, respectively. Alternatively, at least two of the first through fourth heat exchangers may have a common supply water flow path.

**[0026]** In another aspect of the present invention, a cooling/heating system comprises: a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line; a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger; and a supply water heat exchanger, through which the supply water passes, and which is arranged in the bypass line, the supply water heat exchanger heat-exchanging with the refrigerant passing through the bypass line, using the

supply water.

**[0027]** In another aspect of the present invention, a method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger, and a supply water heat exchanger arranged in the bypass line, comprises the steps of: determining whether or not a refrigerant is introduced into the bypass line during a heating operation of the cooling/heating system; and supplying supply water to the supply water heat exchanger when it is determined that the refrigerant is introduced into the bypass line, thereby causing the supply water to heat-exchange with the refrigerant in the supply water heat exchanger.

**[0028]** In another aspect of the present invention, a method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, and a supply water heat exchanger arranged in a predetermined portion of the refrigerant line, comprises the steps of: determining whether or not a refrigerant, which is introduced into the supply water heat exchanger through the refrigerant line, has a temperature not more than a predetermined temperature during a heating operation of the cooling/heating system; and supplying supply water to the supply water heat exchanger when it is determined that the refrigerant temperature is not more than the predetermined temperature, thereby causing the supply water to heat-exchange with the refrigerant in the supply water heat exchanger.

**[0029]** In another aspect of the present invention, a method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, first and second parallel lines included in the refrigerant line and arranged between the expansion device and the compressor, a connecting line arranged between predetermined portions of the first and second parallel lines, a valve arranged in the connecting line to open/close a refrigerant flow path through the connecting line, and a supply water heat exchanger arranged in the second parallel line, the outdoor heat exchanger being arranged in the first parallel line, is characterized in that the valve of the connecting line is opened during a defrosting operation of the cooling/heating system so that supply water is supplied to the supply water heat exchanger via the connecting line and the second parallel line, to heat-exchange with a refrigerant passing through the supply water heat exchanger.

**[0030]** In another aspect of the present invention, a method for controlling a cooling/heating system including

a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, first and second parallel lines included in the refrigerant line and arranged between the expansion device and the compressor, a valve arranged in the second parallel line to open/close a refrigerant flow path through the connecting line, and a supply water heat exchanger arranged in the second parallel line, the outdoor heat exchanger being arranged in the first parallel line, is characterized in that the valve of the second parallel line is opened during a defrosting operation of the cooling/heating system so that supply water is supplied to the supply water heat exchanger via the second parallel line, to heat-exchange with a refrigerant passing through the supply water heat exchanger.

**[0031]** It is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

Embodiments of the invention will now be described by way of non-limiting example only, with reference to the drawings, in which:

**[0032]** FIG. 1A is a block diagram illustrating a cooling/heating system according to a first embodiment of the present invention;

**[0033]** FIG. 1B is a block diagram illustrating a modified example of the cooling/heating system shown in FIG. 1A;

**[0034]** FIG. 2A is a block diagram illustrating a cooling/heating system according to a second embodiment of the present invention;

**[0035]** FIG. 2B is a block diagram illustrating a modified example of the cooling/heating system shown in FIG. 2A;

**[0036]** FIG. 2C is a block diagram illustrating operation of the cooling/heating system shown in FIG. 2A;

**[0037]** FIG. 3A is a block diagram illustrating a cooling/heating system according to a third embodiment of the present invention;

**[0038]** FIG. 3B is a block diagram illustrating a modified example of the cooling/heating system shown in FIG. 3A;

**[0039]** FIG. 4A is a block diagram illustrating a cooling/heating system according to a fourth embodiment of the present invention;

**[0040]** FIG. 4B is a block diagram illustrating a modified example of the cooling/heating system shown in FIG. 4A; and

**[0041]** FIG. 4C is a block diagram illustrating operation of the cooling/heating system shown in FIG. 4A.

Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

**[0042]** Hereinafter, a cooling/heating system according to a first embodiment of the present invention will be described with reference to FIG. 1A.

**[0043]** This cooling/heating system includes a compressor 111, an indoor heat exchanger 112, an expansion device 113, and an outdoor heat exchanger 114 which are connected in series via refrigerant lines, in this

order, to heat exchange a refrigerant flowing through the refrigerant lines with supply water. The supply water means supply water for district heating purposes supplied from an external source such as a cogeneration system or cogeneration power plant. Since such supply water is typically supplied in a hot state, it will be referred to as "hot water" hereinafter.

**[0044]** The hot water is maintained at a temperature of about 70 to 90°C when reaching a building to which the hot water is to be supplied. Thus, such hot water can be effectively applied to a refrigerant cycle.

**[0045]** The refrigerant line arranged between the expansion device 113 and the compressor 111 includes a pair of parallel lines, namely, first and second parallel lines 121 and 122. The outdoor heat exchanger 114 is arranged in the first parallel line 121.

**[0046]** In this embodiment, a first heat exchanger 131 is arranged in the second parallel line 122, to heat-exchange with the refrigerant. Since the first heat exchanger 131 heat-exchanges with the refrigerant using hot water in this case, the first heat exchanger 131 functions as a heater. In heating mode, the first heat exchanger 131 heats the refrigerant, which has been expanded by the expansion device 113, to a gas state, so that the gas refrigerant is introduced into the compressor 111 via the second parallel line 122.

**[0047]** In this embodiment, a connecting line 123 is arranged between predetermined portions of the first and second parallel lines 121 and 122. A valve 135 is also arranged in the connecting line 123, to open/close a refrigerant flow path through the connecting line 123. For the connecting line valve 135, an ON/OFF valve may be used which can simply open/close the refrigerant flow path. In a modification, a solenoid valve is used which can adjust the opening degree of the refrigerant flow path. In another modification the connecting line valve 135 is arranged at a region where the connecting line 123 and the second parallel line 122 are connected. In this case, for the connecting line valve 135, a three-way valve is used which selectively switches the refrigerant emerging from the first heat exchanger 131 between the connecting line 123 and the second parallel line 122.

**[0048]** In the present embodiment, a second heat exchanger 132 is arranged in the first parallel line 121 between the outdoor heat exchanger 114 and the compressor 111, to heat-exchange with the refrigerant. Since the second heat exchanger 132 heat-exchanges with the refrigerant using hot water in this case, the third heat exchanger 133 practically functions as a heater. A third heat exchanger 133 is arranged in a refrigerant line 124 arranged between the compressor 111 and the indoor heat exchanger 112, to heat-exchange with the refrigerant. Since the third heat exchanger 133 heat-exchanges with the refrigerant using hot water in this case, the third heat exchanger 133 practically functions as a heater.

**[0049]** Temperature sensors 131a, 132a, and 133a are arranged at respective refrigerant outlet sides of the first, second, and third heat exchangers 131, 132, and

133. In a modification, not shown, temperature sensors are arranged at any one or two of the first, second, and third heat exchangers 131, 132, and 133. For example, one temperature sensor can be arranged at the first heat exchanger 131, the second heat exchanger 132, or the third heat exchanger 133. Alternatively, two temperature sensors can be arranged at the first and second heat exchangers 131 and 132, the second and third heat exchangers 132 and 133, or the first and third heat exchangers 131 and 133, respectively.

[0050] In this embodiment each of the first, second, and third heat exchangers 131, 132, and 133 includes heat transfer fins formed around the refrigerant line passing through the associated heat exchanger, and a hot water line arranged to heat-exchange with the refrigerant line formed with the heat transfer fins. However, the provision of such fins is not essential. The hot water line forms a double pipe structure, together with the associated refrigerant line. In this structure, the flow directions of the refrigerant and hot water may be identical or opposite to each other. In terms of heat exchange efficiency, it is preferred that the flow directions of the refrigerant and hot water be opposite to each other. However, the double pipe structure is not essential and the heat exchangers may have various structures other than the above-described structure, so long as the refrigerant can come into thermal contact with the hot water.

[0051] The hot water lines of the first, second, and third heat exchangers 131, 132, and 133 are independent to provide independent hot water flow paths for the heat exchangers, respectively, as shown in FIG. 1A. Valves 131b, 132b, and 133b are arranged in the hot water lines, respectively. Accordingly, when the temperature of the refrigerant, which passes through any one of the heat exchangers 131, 132, and 133, is lower than the temperature of the hot water by a predetermined value or more, the hot water may be supplied to the associated heat exchanger. If not, the supply of the hot water may be cut off.

[0052] It will also be appreciated that the hot water lines of at least two of the first, second, and third heat exchangers 131, 132, and 133 may be connected together in the form of a common hot water line to provide a common hot water flow path, as shown in FIG. 1B. In this case, it is advantageous that the common hot water line first pass through the heat exchanger which is required to heat the refrigerant in the heating mode. For example, the common hot water line may first pass through the third heat exchanger 133.

[0053] Operation of the above-described cooling/heating system will now be described with reference to FIG. 1A.

[0054] When the heating operation of the system is initiated, the refrigerant flows in a dotted-line direction shown in FIG. 1A.

[0055] That is, the refrigerant is introduced into the third heat exchanger 133 after being compressed by the compressor 111. At this time, introduction of the hot water

is carried out only when it is determined that the temperature of the refrigerant is outside a predetermined temperature range set in a controller (not shown). The introduced hot water increases the temperature of the refrigerant when the temperature of the refrigerant is low, and decreases the temperature of the refrigerant when the temperature of the refrigerant is high. Thus, the refrigerant discharged from the compressor 111 can be maintained in the predetermined temperature range.

[0056] The refrigerant emerging from the third heat exchanger 133 is introduced into the indoor heat exchanger 112 which, in turn, condenses the introduced refrigerant. The indoor heat exchanger 112 then heat-exchanges with air present in a confined space, for example, a room, to be air-conditioned, thereby heating the room.

[0057] The refrigerant emerging from the indoor heat exchanger 112 is then introduced into the second parallel line 122 after being expanded by the expansion device 113. The refrigerant introduced into the second parallel line 122 is heated while passing through the first heat exchanger 131, so that the refrigerant is changed from a two-phase state to a gas phase. The refrigerant emerging from the second parallel line 122 is introduced again into the compressor 111. Since the refrigerant introduced into the compressor 111 is a gas refrigerant maintained at a temperature higher than that of the expanded refrigerant, the compression work of the compressor 111 is reduced.

[0058] While the above-described heating operation is continued for a predetermined time, the outdoor heat exchanger 114 is exposed to ambient air. For this reason, frost may be formed on the surface of the outdoor heat exchanger 114 when ambient temperature is very low (about -15°C or below). In this case, accordingly, a defrosting operation must be carried out to remove the frost.

[0059] When the defrosting operation is initiated, the refrigerant flows in a solid-line direction shown in FIG. 1A.

[0060] That is, the controller controls the connecting line valve 135 to be opened. As a result, the expanded refrigerant introduced into the second parallel line 122 is branched into the connecting line 123 and the second parallel line 122 after heat-exchanging with the hot water in the first heat exchanger 131. The fraction of the expanded refrigerant introduced into the connecting line 123 melts the frost formed on the outdoor heat exchanger 114 while passing through the outdoor heat exchanger 114, and then enters the compressor 111 after being heated in the second heat exchanger 132. Also, the remaining fraction of the expanded refrigerant is introduced into the compressor 111 via the second parallel line 122. Thus, the temperature of the refrigerant supplied to the compressor 111 is relatively high, so that the compression work of the compressor 111 can be reduced. Also, since the defrosting operation is carried out during the heating operation, the heating operation can be continuously carried out.

[0061] On the other hand, although not shown, the refrigerant compressed in the compressor 111 is intro-

duced into the first parallel line 121 in cooling mode. In this case, the refrigerant from the first parallel line 121 is then introduced into the expansion device 113 after sequentially passing through the second heat exchanger 132 and outdoor heat exchanger 114. The refrigerant expanded by the expansion device 113 is introduced into the compressor 111 after sequentially passing through the indoor heat exchanger 112 and third heat exchanger 133.

**[0062]** A second embodiment will now be described with reference to FIG. 2A.

**[0063]** The second embodiment is different from the first embodiment in that the cooling/heating system further includes a bypass line.

**[0064]** This cooling/heating system includes a compressor 111, an indoor heat exchanger 112, an expansion device 113, and an outdoor heat exchanger 114 which are connected in series via refrigerant lines, in this order. The refrigerant line arranged between the expansion device 113 and the compressor 111 includes a first parallel line 121 and a second parallel line 122. The outdoor heat exchanger 114 is arranged in the first parallel line 121. A first heat exchanger 131 is arranged in the second parallel line 122. A connecting line 123 is also arranged to connect the first and second parallel lines 121 and 122. A valve 135 is also arranged in the connecting line 123. A second heat exchanger 132 is arranged in the first parallel line 121 between the outdoor heat exchanger 114 and the compressor 111. Also, a third heat exchanger 133 is arranged in a refrigerant line 124 arranged between the compressor 111 and the indoor heat exchanger 112. Temperature sensors 131a, 132a, and 133a are arranged at respective refrigerant outlet sides of the first, second, and third heat exchangers 131, 132, and 133. The above-described constituent elements are substantially identical to those of the first embodiment, and, accordingly, no detailed description thereof will be given.

**[0065]** A bypass line 141 is connected to the refrigerant line 125 between the expansion device 113 and the indoor heat exchanger 112, and to the refrigerant line between the compressor 111 and the outdoor heat exchanger 114. In this embodiment a fourth heat exchanger 134 is arranged in the bypass line 141, to heat-exchange with the refrigerant. In this case, the fourth heat exchanger 134 heats the refrigerant bypassed through the bypass line 141 using hot water, so as to enable a gas-phase refrigerant to be introduced into the compressor 111.

**[0066]** In this embodiment a check valve 142 is arranged in the bypass line 141. The check valve 142 is open when the pressure of the refrigerant is not lower than a predetermined pressure. Where the compressor 111 compresses the refrigerant through two stages, the check valve 142 opens in response to the pressure of the primarily compressed refrigerant. In this state, accordingly, a fraction of the primarily compressed refrigerant is introduced into the compressor 111 via the bypass line 141. The refrigerant introduced into the com-

pressor 111 is then secondarily compressed by the compressor 111. When the refrigerant is double-compressed in such a manner, a remarkable increase in compression efficiency is achieved.

**[0067]** In the illustrated embodiment the check valve 142 is arranged at the refrigerant inlet side of the fourth heat exchanger 134. Of course, the check valve 142 may alternatively be arranged at the refrigerant outlet side of the fourth heat exchanger 134. However, where the check valve 142 is arranged at the refrigerant outlet side of the fourth heat exchanger 134, the refrigerant may be unnecessarily accumulated in the fourth heat exchanger 134, thereby causing a refrigerant shortage. In order to fundamentally eliminate such refrigerant shortage phenomenon, it is preferred that the check valve 142 be arranged at the refrigerant inlet side of the check valve 142.

**[0068]** In the illustrated embodiment a temperature sensor 134a is arranged at the refrigerant outlet side of the fourth heat exchanger 134. The temperature sensor 134a determines the temperature of the refrigerant discharged from the fourth heat exchanger 134, and controls the amount of hot water supplied to the fourth heat exchanger 134, based on the determined discharge temperature of the refrigerant. For example, when the temperature of the refrigerant is low, the temperature sensor 134a performs a control operation to supply a relatively large amount of hot water to the fourth heat exchanger 134. Other positions of the temperature sensor are possible.

**[0069]** The first, second, third, and fourth heat exchangers 131, 132, 133, and 141 include independent hot water lines to provide independent hot water flow paths for the heat exchangers, respectively, as shown in FIG. 2A. Valves 131b, 132b, 133b, and 134b are arranged in the hot water lines, respectively. Accordingly, when the temperature of the refrigerant, which passes through any one of the heat exchangers 131, 132, 133, and 134, is lower than the temperature of the hot water by a predetermined value or more, the hot water is supplied to the associated heat exchanger. If not, the supply of the hot water is cut off.

**[0070]** It will also be appreciated that the hot water lines of at least two of the first, second, third, and fourth heat exchangers 131, 132, 133, and 134 may be connected together in the form of a common hot water line to provide a common hot water flow path, as shown in FIG. 2B. In this case, it is advantageous that the common hot water line first pass through the heat exchanger which is required to heat the refrigerant in the heating mode.

**[0071]** Operation of the above-described cooling/heating system according to the second embodiment will now be described. The operation of the second embodiment is substantially identical to the operation described in conjunction with the first embodiment. That is, the refrigerant flows in a dotted-line direction shown in FIG. 2A in the heating mode of the cooling/heating system, and flows in a solid-line direction shown in FIG. 2A in the defrosting mode of the cooling/heating system. Provided,

where the compressor 111 compresses the refrigerant through two stages in the heating mode, a fraction of the refrigerant primarily compressed by the compressor 111 is introduced into the bypass line 141, so that the introduced refrigerant applies a certain pressure to the check valve 142, as shown in FIG. 2C. As the check valve 142 is opened by the refrigerant pressure, a fraction of the refrigerant primarily compressed by the compressor 111 is introduced into the fourth heat exchanger 134 via the bypass line 141. In the fourth heat exchanger 134, the introduced refrigerant heat-exchanges with hot water, so that the refrigerant is changed to a gas state. The gas refrigerant is introduced again into the compressor 111 which, in turn, secondarily compresses the refrigerant. Thus, the refrigerant compressed through two stages flows throughout the system.

**[0072]** Hereinafter, a method for controlling the above-described cooling/heating system will be described.

**[0073]** When it is determined in the heating mode that hot water is to be introduced into the fourth heat exchanger 134, the controller (not shown) performs a control operation to supply hot water to the fourth heat exchanger 134.

**[0074]** Also, when it is determined in the heating mode that the temperature of any one of the first through fourth heat exchangers is not more than a predetermined temperature set in the controller, the controller performs a control operation to supply hot water to the associated heat exchanger. The predetermined temperature of each heat exchanger must be appropriately set, taking into consideration the heating capacity and cooling capacity of the system.

**[0075]** Now, a cooling/heating system according to a third embodiment of the present invention will be described with reference to FIG. 3A.

**[0076]** This cooling/heating system includes a compressor 161, an indoor heat exchanger 162, an expansion device 163, and an outdoor heat exchanger 164 which are connected in series via refrigerant lines, in this order, to heat exchange a refrigerant flowing through the refrigerant lines with supply water in heating mode.

**[0077]** The refrigerant line arranged between the expansion device 163 and the outdoor heat exchanger 164 includes a first parallel line 171 and a second parallel line 172. A first heat exchanger 181 is arranged in the second parallel line 172, to heat-exchange with the refrigerant. Since the first heat exchanger 181 heat-exchanges with the refrigerant using hot water in this case, the first heat exchanger 181 functions as a heater. A valve 185 is arranged in the second parallel line 172, to control a refrigerant flow path through the second parallel line 172. In the present embodiment the valve 185, is an ON/OFF valve which can simply open/close the refrigerant flow path. Of course, a solenoid valve may alternatively be used which can adjust the opening degree of the refrigerant flow path. In a further modification, not shown, the valve 185 is arranged at a region where the first and second parallel lines 171 and 172 are connected. In this

case, for the valve 185, a three-way valve can be used which selectively switches the refrigerant emerging from the expansion device 163 between the first parallel line 171 and the second parallel line 172.

**[0078]** In this embodiment a second heat exchanger 182 is arranged in the refrigerant line 171 between the outdoor heat exchanger 164 and the compressor 161, to heat-exchange with the refrigerant. Since the second heat exchanger 182 heat-exchanges with the refrigerant using hot water in this case, the second heat exchanger 182 functions as a heater. It is also preferred that a third heat exchanger 183 be arranged in a refrigerant line 174 arranged between the compressor 161 and the indoor heat exchanger 162, to heat-exchange with the refrigerant. Since the third heat exchanger 183 heat-exchanges with the refrigerant using hot water in this case, the third heat exchanger 183 functions as a heater.

**[0079]** Also, preferably, temperature sensors 181a, 182a, and 183a are arranged at respective refrigerant outlet sides of the first, second, and third heat exchangers 181, 182, and 183. Alternatively, such a temperature sensor may be arranged at any one or two of the first, second, and third heat exchangers 181, 182, and 183. For example, one temperature sensor may be arranged at the first heat exchanger 181, the second heat exchanger 182, or the third heat exchanger 183. Alternatively, two temperature sensors may be arranged at the first and second heat exchangers 181 and 182, the second and third heat exchangers 182 and 183, or the first and third heat exchangers 181 and 183, respectively.

**[0080]** Each of the first, second, and third heat exchangers 181, 182, and 183 may include heat transfer fins formed around the refrigerant line passing through the associated heat exchanger, and a hot water line arranged to heat-exchange with the refrigerant line formed with the heat transfer fins. The hot water line may form a double pipe structure, together with the associated refrigerant line. In this structure, the flow directions of the refrigerant and hot water may be identical or opposite to each other. In terms of heat exchange efficiency, it is preferred that the flow directions of the refrigerant and hot water be opposite to each other. The heat exchangers may have various structures other than the above-described structure, so long as the refrigerant can come into thermal contact with the hot water.

**[0081]** As shown in FIG. 3A, the hot water lines of the first, second, and third heat exchangers 181, 182, and 183 are independent to provide independent hot water flow paths for the heat exchangers, respectively. Valves 181b, 182b, and 183b are arranged in the hot water lines, respectively. Accordingly, when the temperature of the refrigerant, which passes through any one of the heat exchangers 181, 182, and 183, is lower than the temperature of the hot water by a predetermined value or more, the hot water can be supplied to the associated heat exchanger. If not, the supply of the hot water can be cut off.

**[0082]** It will also be appreciated that the hot water lines of at least two of the first, second, and third heat exchang-

ers 181, 182, and 183 may be connected together in the form of a common hot water line to provide a common hot water flow path, as shown in FIG. 3B. In this case, it is preferred that the common hot water line first pass through the heat exchanger which is required to heat the refrigerant in the heating mode.

**[0083]** Operation of the above-described cooling/heating system will now be described.

**[0084]** When the heating operation of the system is initiated, the refrigerant flows in a dotted-line direction shown in FIG. 3A.

**[0085]** That is, the refrigerant is introduced into the third heat exchanger 183 after being compressed by the compressor 161. Introduction of the hot water is carried out only when it is determined that the temperature of the refrigerant is outside a predetermined temperature range set in a controller (not shown). The introduced hot water increases the temperature of the refrigerant when the temperature of the refrigerant is low, and decreases the temperature of the refrigerant when the temperature of the refrigerant is high. Thus, the refrigerant discharged from the compressor 161 can be maintained within the predetermined temperature range.

**[0086]** The refrigerant emerging from the third heat exchanger 183 is introduced into the indoor heat exchanger 162 which, in turn, condenses the introduced refrigerant. The indoor heat exchanger 162 then heat-exchanges with air present in a room to be air-conditioned, thereby heating the room.

**[0087]** The refrigerant emerging from the indoor heat exchanger 162 is then introduced into the first parallel line 171 after being expanded by the expansion device 163. The refrigerant introduced into the first parallel line 171 heat-exchanges with ambient air while passing through the outdoor heat exchanger 164. Subsequently, the refrigerant is heated while passing through the second heat exchanger 182, so that the refrigerant is changed from a two-phase state to a gas phase. The refrigerant is introduced again into the compressor 161. Since the refrigerant introduced into the compressor 161 is a gas refrigerant maintained at a temperature higher than that of the expanded refrigerant, the compression work of the compressor 161 is reduced.

**[0088]** While the above-described heating operation is continued for a predetermined time, the outdoor heat exchanger 164 is exposed to ambient air. For this reason, when ambient temperature is very low (about -15°C or below), frost may be formed on the surface of the outdoor heat exchanger 164 because the low-temperature refrigerant is continuously introduced into the outdoor heat exchanger 164. In this case, accordingly, a defrosting operation must be carried out to remove the frost.

**[0089]** When the defrosting operation is initiated, the refrigerant flows in a solid-line direction shown in FIG. 3A.

**[0090]** That is, the controller controls the valve 185 of the second parallel line 172 to be opened. As a result, the expanded refrigerant is introduced into the second parallel line 172. Subsequently, the expanded refrigerant

enters the outdoor heat exchanger 164 after heat-exchanging with hot water in the first heat exchanger 181. The expanded refrigerant melts the frost formed on the outdoor heat exchanger 164 while passing through the outdoor heat exchanger 164, and then enters the second heat exchanger 182. Simultaneously, the expanded refrigerant passing through the first parallel line 171 is introduced into the second heat exchanger 182 via the outdoor heat exchanger 164. The expanded refrigerant then enters the compressor 161 after being heated in the second heat exchanger 182. Thus, the temperature of the refrigerant supplied to the compressor 161 is relatively high, so that the compression work of the compressor 161 can be reduced.

**[0091]** On the other hand, in cooling mode, the refrigerant compressed in the compressor 161 sequentially passes through the second heat exchanger 182, outdoor heat exchanger 164, expansion device 163, indoor heat exchanger 162, and third heat exchanger 183, in this order, and then re-enters the compressor 161.

**[0092]** Hereinafter, a cooling/heating system according to a fourth embodiment of the present invention will be described with reference to FIG. 4A.

**[0093]** The fourth embodiment is different from the third embodiment in that the cooling/heating system further includes a bypass line.

**[0094]** This cooling/heating system includes a compressor 161, an indoor heat exchanger 162, an expansion device 163, and an outdoor heat exchanger 164 which are connected in series via refrigerant lines, in this order. The refrigerant line arranged between the expansion device 163 and the outdoor heat exchanger 164 includes a first parallel line 171 and a second parallel line 172. A first heat exchanger 181 is arranged in the second parallel line 172. A valve 185 is arranged in the second parallel line 172. A second heat exchanger 182 is arranged in the first parallel line 171 between the outdoor heat exchanger 164 and the compressor 161. Also, a third heat exchanger 183 is arranged in a refrigerant line 174 arranged between the compressor 161 and the indoor heat exchanger 162. Temperature sensors 181a, 182a, and 183a are arranged at respective refrigerant outlet sides of the first, second, and third heat exchangers 181, 182, and 183. Valves 181b, 182b, and 183b are also arranged in the first, second, and third heat exchangers 181, 182, and 183, respectively. The above-described constituent elements are substantially identical to those of the third embodiment, and, accordingly, no detailed description thereof will be given.

**[0095]** A bypass line 191 is connected to the refrigerant line 175 between the expansion device 163 and the indoor heat exchanger 162, and to the refrigerant line between the compressor 161 and the outdoor heat exchanger 164. In this embodiment a fourth heat exchanger 184 is arranged in the bypass line 191, to heat-exchange with the refrigerant. Since the fourth heat exchanger 184 heat-exchanges with the refrigerant using hot water in this case, the fourth heat exchanger 184 functions as a

heater. In this case, the fourth heat exchanger 184 heats the refrigerant bypassed through the bypass line 191, so as to enable a gas-phase refrigerant to be introduced into the compressor 161.

**[0096]** In this embodiment a check valve 192 is arranged in the bypass line 191. The check valve 192 opens when the pressure of the refrigerant is not lower than a predetermined pressure. Where the compressor 161 compresses the refrigerant through two stages, the check valve 192 opens in response to the pressure of the primarily compressed refrigerant. In this state, accordingly, a fraction of the primarily compressed refrigerant is introduced into the compressor 161 via the bypass line 191. The refrigerant introduced into the compressor 161 is then secondarily compressed by the compressor 161. When the refrigerant is double-compressed in such a manner, a remarkable increase in compression efficiency is achieved.

**[0097]** In the present embodiment the check valve 192 is arranged at the refrigerant inlet side of the fourth heat exchanger 184. Of course, the check valve 192 may alternatively be arranged at the refrigerant outlet side of the fourth heat exchanger 184. However, where the check valve 192 is arranged at the refrigerant outlet side of the fourth heat exchanger 184, the refrigerant may be unnecessarily accumulated in the fourth heat exchanger 184, thereby causing a refrigerant shortage. In order to fundamentally eliminate such refrigerant shortage phenomenon, it is preferred that the check valve 192 be arranged at the refrigerant inlet side of the check valve 192.

**[0098]** In this embodiment a temperature sensor 184a is arranged at the refrigerant outlet side of the fourth heat exchanger 184. The temperature sensor 184a determines the temperature of the refrigerant discharged from the fourth heat exchanger 184, and controls the amount of hot water supplied to the fourth heat exchanger 184, based on the determined discharge temperature of the refrigerant. For example, when the temperature of the refrigerant is low, the temperature sensor 184a performs a control operation to supply a relatively large amount of hot water to the fourth heat exchanger 184. However, other locations for the temperature sensor are possible.

**[0099]** The first, second, and third heat exchangers 181, 182, and 183 include independent hot water lines to provide independent hot water flow paths, respectively, as shown in FIG. 4A. In this case, the valves 181b, 182b, and 183b are arranged in the hot water lines, respectively. Accordingly, when the temperature of the refrigerant, which passes through any one of the heat exchangers 181, 182, and 183, is lower than the temperature of the hot water by a predetermined value or more, the hot water is supplied to the associated heat exchanger. If not, the supply of the hot water is cut off.

**[0100]** It will also be appreciated that the hot water lines of at least two of the first, second, and third heat exchangers 181, 182, and 183 may be connected together in the form of a common hot water line to provide a common hot water flow path, as shown in FIG. 4B. In this case, it

is preferred that the common hot water line first pass through the heat exchanger which is required to heat the refrigerant in the heating mode.

**[0101]** Operation of the above-described cooling/heating system according to the fourth embodiment will now be described. The operation of the fourth embodiment is substantially identical to the operation described in conjunction with the third embodiment. That is, the refrigerant flows in a dotted-line direction shown in FIG. 4A in the heating mode of the cooling/heating system, and flows in a solid-line direction shown in FIG. 4A in the defrosting mode of the cooling/heating system. Provided, where the compressor 161 compresses the refrigerant through two stages in the heating mode, a fraction of the refrigerant primarily compressed by the compressor 161 is introduced into the bypass line 191, so that the introduced refrigerant applies a certain pressure to the check valve 192. As the check valve 192 is opened by the refrigerant pressure, a fraction of the refrigerant primarily compressed by the compressor 161 is introduced into the fourth heat exchanger 184 via the bypass line 191, as shown in FIG. 4C. In the fourth heat exchanger 184, the introduced refrigerant heat-exchanges with hot water, so that the refrigerant is changed to a gas state. The gas refrigerant is introduced again into the compressor 161 which, in turn, secondarily compresses the refrigerant. Thus, the refrigerant compressed through two stages flows throughout the system.

**[0102]** Hereinafter, a method for controlling the above-described cooling/heating system will be described.

**[0103]** When it is determined in the heating mode that hot water is to be introduced into the fourth heat exchanger 184, the controller (not shown) performs a control operation to supply hot water to the fourth heat exchanger 184.

**[0104]** Also, when it is determined in the heating mode that the temperature of any one of the first through fourth heat exchangers is not more than a predetermined temperature set in the controller, the controller performs a control operation to supply hot water to the associated heat exchanger. The predetermined temperature of each heat exchanger must be appropriately set, taking into consideration the heating capacity and cooling capacity of the system.

**[0105]** The above-described cooling/heating system according to the present invention provides the following effects.

**[0106]** First, in accordance with the present invention, it is unnecessary to additionally use an indoor unit for heating purposes using hot water. Accordingly, the maintenance and repair costs are reduced.

**[0107]** Second, since the refrigerant is introduced into the compressor after being heated by hot water in accordance with the present invention, it is possible to reduce the compression work of the compressor, and to reduce power consumption.

**[0108]** Third, since the defrosting operation is carried out simultaneously with the heating operation in accord-

ance with the present invention, it is possible to implement a continuous heating operation.

**[0109]** It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents. For example, while the bypass circuits of the embodiments have included heat exchangers, these are not essential.

## Claims

### 1. A cooling/heating system comprising:

a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, and means for exchanging heat between a refrigerant, which flows through the refrigerant line, and supply water.

### 2. The cooling/heating system according to claim 1, wherein:

the refrigerant line comprises a first parallel line and a second parallel line which are arranged between the expansion device and the compressor; and the outdoor heat exchanger is arranged in the first parallel line.

### 3. The cooling/heating system according to claim 2, further comprising:

a first heat exchanger, through which the supply water passes, and which is arranged in the second parallel line, the first heat exchanger heat-exchanging with the refrigerant passing through the second parallel line, using the supply water.

### 4. The cooling/heating system according to claim 3, further comprising:

a connecting line arranged between predetermined portions of the first and second parallel lines; and a valve arranged in the connecting line to open/close a refrigerant flow path through the connecting line.

### 5. The cooling/heating system according to claim 2, further comprising:

a second heat exchanger, through which the

supply water passes, and which is arranged in the first parallel line between the outdoor heat exchanger and the compressor, the second heat exchanger heat-exchanging with the refrigerant passing through the first parallel line, using the supply water.

### 6. The cooling/heating system according to claim 2, further comprising:

a third heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the compressor and the indoor heat exchanger, the third heat exchanger heat-exchanging with the refrigerant passing through the refrigerant line between the compressor and the indoor heat exchanger, using the supply water.

### 7. The cooling/heating system according to claim 2, further comprising:

a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger.

### 8. The cooling/heating system according to claim 7, further comprising:

a fourth heat exchanger, through which the supply water passes, and which is arranged in the bypass line, the fourth heat exchanger heat-exchanging with the refrigerant passing through the bypass line, using the supply water.

### 9. The cooling/heating system according to claim 8, further comprising:

a check valve arranged at a refrigerant inlet side of the fourth heat exchanger.

### 10. The cooling/heating system according to claim 3, further comprising:

a second heat exchanger, through which the supply water passes, and which is arranged in the first parallel line between the outdoor heat exchanger and the compressor, the second heat exchanger heat-exchanging with the refrigerant passing through the first parallel line, using the supply water.

### 11. The cooling/heating system according to claim 10, further comprising:

- a third heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the compressor and the indoor heat exchanger, the third heat exchanger heat-exchanging with the refrigerant passing through the refrigerant line between the compressor and the indoor heat exchanger, using the supply water.
- 12.** The cooling/heating system according to claim 11, further comprising:
- a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger.
- 13.** The cooling/heating system according to claim 12, further comprising:
- a fourth heat exchanger, through which the supply water passes, and which is arranged in the bypass line, the fourth heat exchanger heat-exchanging with the refrigerant passing through the bypass line, using the supply water.
- 14.** The cooling/heating system according to claim 13, wherein the first through fourth heat exchangers have independent supply water flow paths, respectively.
- 15.** The cooling/heating system according to claim 13, wherein at least two of the first through fourth heat exchangers have a common supply water flow path.
- 16.** The cooling/heating system according to claim 1, wherein the refrigerant line comprises a first parallel line and a second parallel line which are arranged between the expansion device and the outdoor heat exchanger, further comprising:
- a first heat exchanger, through which the supply water passes, and which is arranged in the second parallel line, the first heat exchanger heat-exchanging with the refrigerant passing through the second parallel line, using the supply water.
- 17.** The cooling/heating system according to claim 16, further comprising:
- a valve arranged in the second parallel line to open/close a refrigerant flow path through the connecting line.
- 18.** The cooling/heating system according to claim 17,
- wherein the valve is arranged at a refrigerant inlet side of the first heat exchanger.
- 19.** The cooling/heating system according to claim 16, further comprising:
- a second heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the outdoor heat exchanger and the compressor, the second heat exchanger heat-exchanging with the refrigerant passing through the refrigerant line, using the supply water.
- 20.** The cooling/heating system according to claim 16, further comprising:
- a third heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the compressor and the indoor heat exchanger, the third heat exchanger heat-exchanging with the refrigerant passing through the refrigerant line between the compressor and the indoor heat exchanger, using the supply water.
- 21.** The cooling/heating system according to claim 16, further comprising:
- a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger.
- 22.** The cooling/heating system according to claim 21, further comprising:
- a fourth heat exchanger, through which the supply water passes, and which is arranged in the bypass line, the fourth heat exchanger heat-exchanging with the refrigerant passing through the bypass line, using the supply water.
- 23.** The cooling/heating system according to claim 22, further comprising:
- a check valve arranged at a refrigerant inlet side of the fourth heat exchanger.
- 24.** The cooling/heating system according to claim 19, further comprising:
- a third heat exchanger, through which the supply water passes, and which is arranged in the refrigerant line between the compressor and the indoor heat exchanger, the third heat exchanger

heat-exchanging with the refrigerant passing through the refrigerant line between the compressor and the indoor heat exchanger, using the supply water.

- 25.** The cooling/heating system according to claim 24, further comprising:

a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger.

- 26.** The cooling/heating system according to claim 25, further comprising:

a fourth heat exchanger, through which the supply water passes, and which is arranged in the bypass line, the fourth heat exchanger heat-exchanging with the refrigerant passing through the bypass line, using the supply water.

- 27.** The cooling/heating system according to claim 26, further comprising:

a temperature sensor arranged at a refrigerant outlet side of at least one of the first through fourth heat exchangers.

- 28.** The cooling/heating system according to claim 26, wherein the first through fourth heat exchangers have independent supply water flow paths, respectively.

- 29.** The cooling/heating system according to claim 26, wherein at least two of the first through fourth heat exchangers have a common supply water flow path.

- 30.** A cooling/heating system comprising:

a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line;

a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger; and

a supply water heat exchanger, through which the supply water passes, and which is arranged in the bypass line, the supply water heat exchanger heat-exchanging with the refrigerant passing through the bypass line, using the supply water.

- 31.** The cooling/heating system according to claim 30, further comprising:

a check valve arranged at a refrigerant inlet side of the supply water heat exchanger.

- 32.** A method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, a bypass line connected between a portion of the refrigerant line arranged between the expansion device and the indoor heat exchanger and a portion of the refrigerant line arranged between the compressor and the outdoor heat exchanger, and a supply water heat exchanger arranged in the bypass line, the method comprising the steps of:

determining whether or not a refrigerant is introduced into the bypass line during a heating operation of the cooling/heating system; and supplying supply water to the supply water heat exchanger when it is determined that the refrigerant is introduced into the bypass line, thereby causing the supply water to heat-exchange with the refrigerant in the supply water heat exchanger.

- 33.** A method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, and a supply water heat exchanger arranged in a predetermined portion of the refrigerant line, the method comprising the steps of:

determining whether or not a refrigerant, which is introduced into the supply water heat exchanger through the refrigerant line, has a temperature not more than a predetermined temperature during a heating operation of the cooling/heating system; and supplying supply water to the supply water heat exchanger when it is determined that the refrigerant temperature is not more than the predetermined temperature, thereby causing the supply water to heat-exchange with the refrigerant in the supply water heat exchanger.

- 34.** A method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, first and second parallel lines included in the refrigerant line and arranged between the expansion device and the compressor, a connecting line arranged between predetermined portions of the first and second parallel lines, a valve arranged in the

connecting line to open/close a refrigerant flow path through the connecting line, and a supply water heat exchanger arranged in the second parallel line, the outdoor heat exchanger being arranged in the first parallel line,

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wherein the valve of the connecting line is opened during a defrosting operation of the cooling/heating system so that supply water is supplied to the supply water heat exchanger via the connecting line and the second parallel line, to heat-exchange with a refrigerant passing through the supply water heat exchanger.

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- 35.** A method for controlling a cooling/heating system including a compressor, an indoor heat exchanger, an expansion device, and an outdoor heat exchanger which are connected in series via a refrigerant line, first and second parallel lines included in the refrigerant line and arranged between the expansion device and the compressor, a valve arranged in the second parallel line to open/close a refrigerant flow path through the connecting line, and a supply water heat exchanger arranged in the second parallel line, the outdoor heat exchanger being arranged in the first parallel line,

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wherein the valve of the second parallel line is opened during a defrosting operation of the cooling/heating system so that supply water is supplied to the supply water heat exchanger via the second parallel line, to heat-exchange with a refrigerant passing through the supply water heat exchanger.

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FIG. 1A

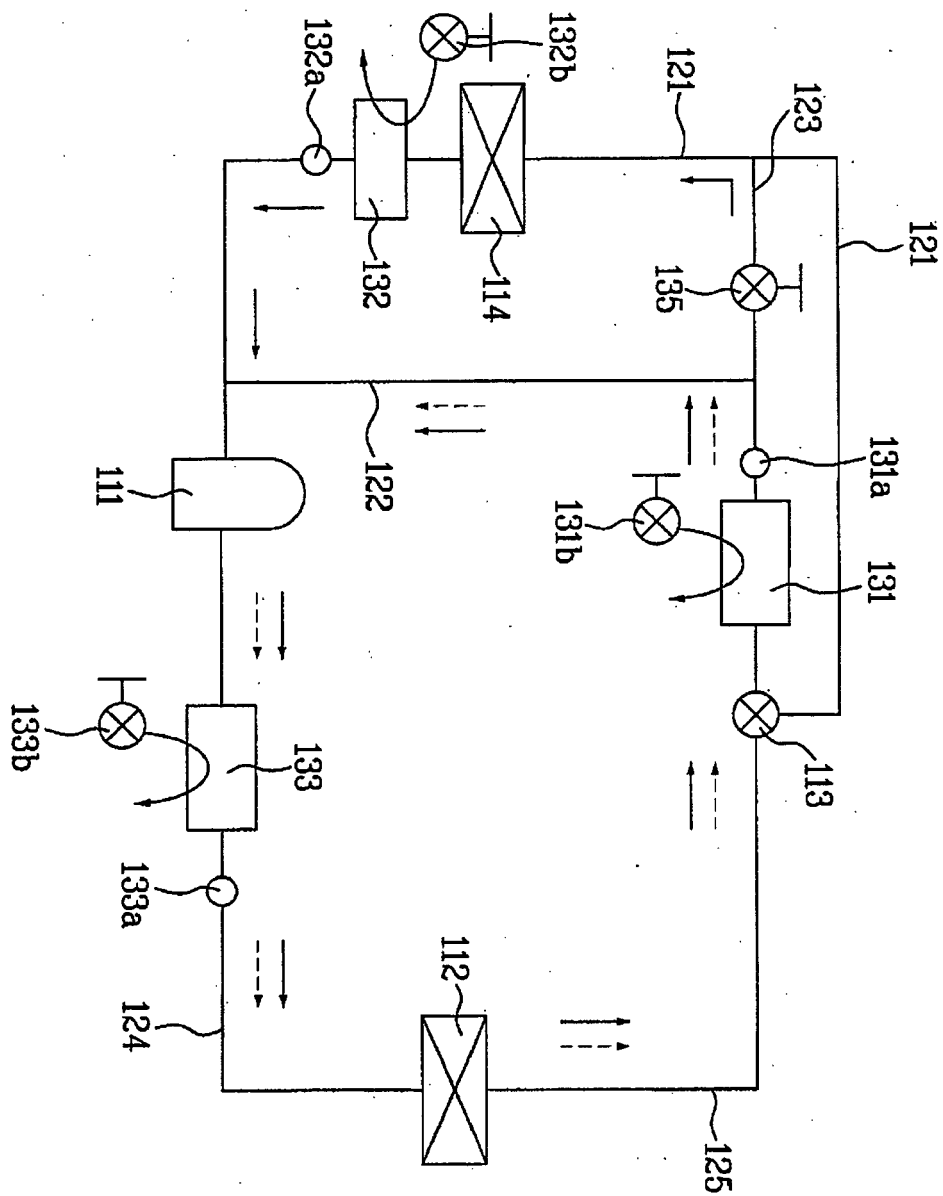


FIG. 1B

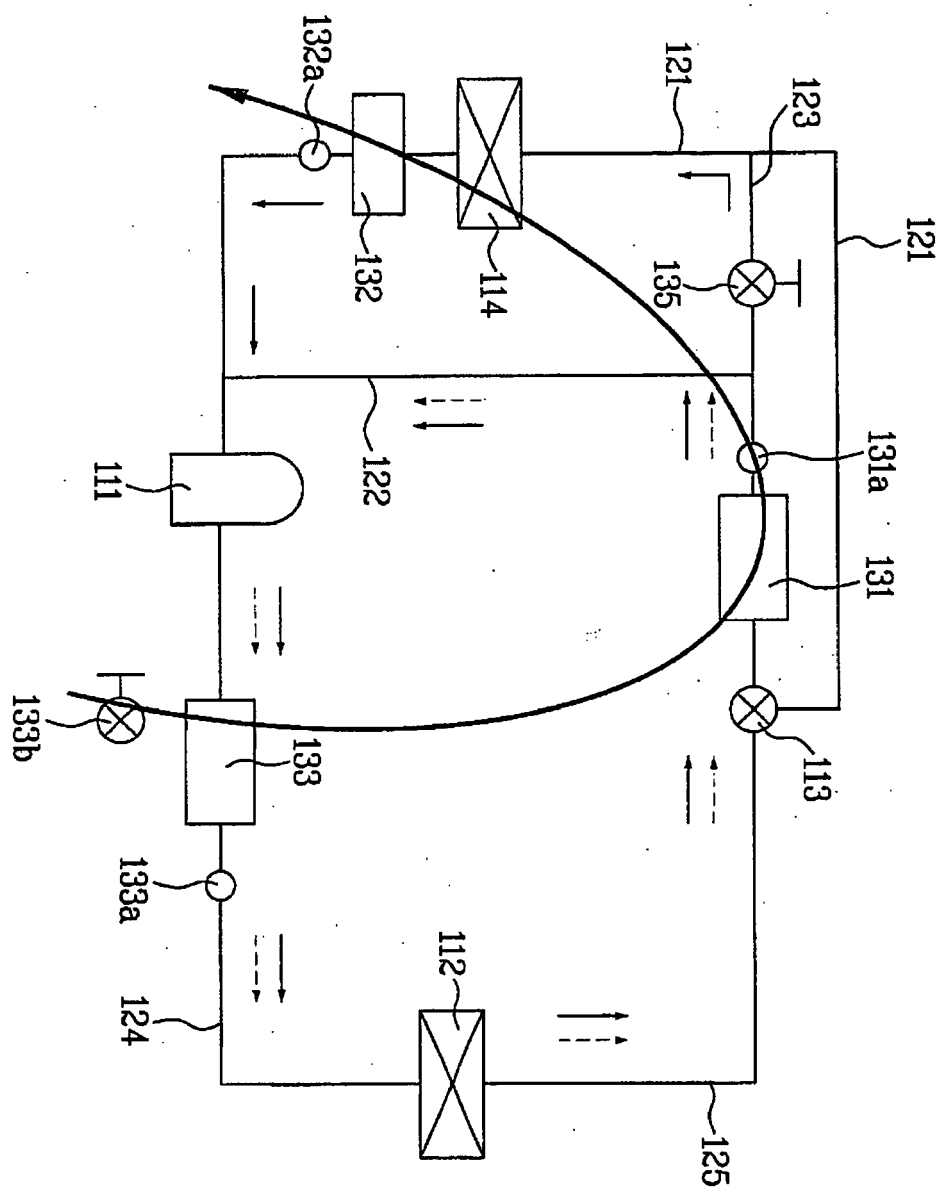


FIG. 2A

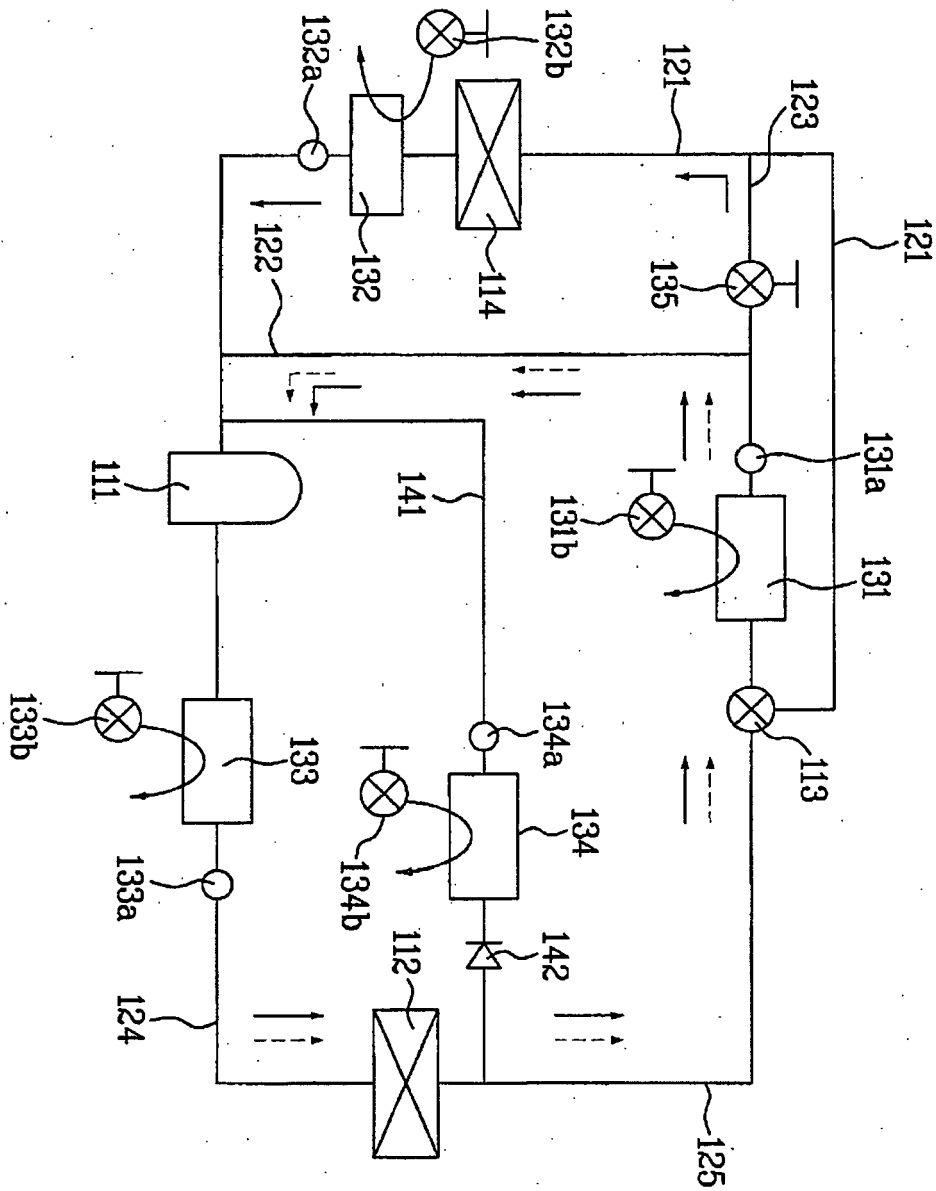


FIG. 2B

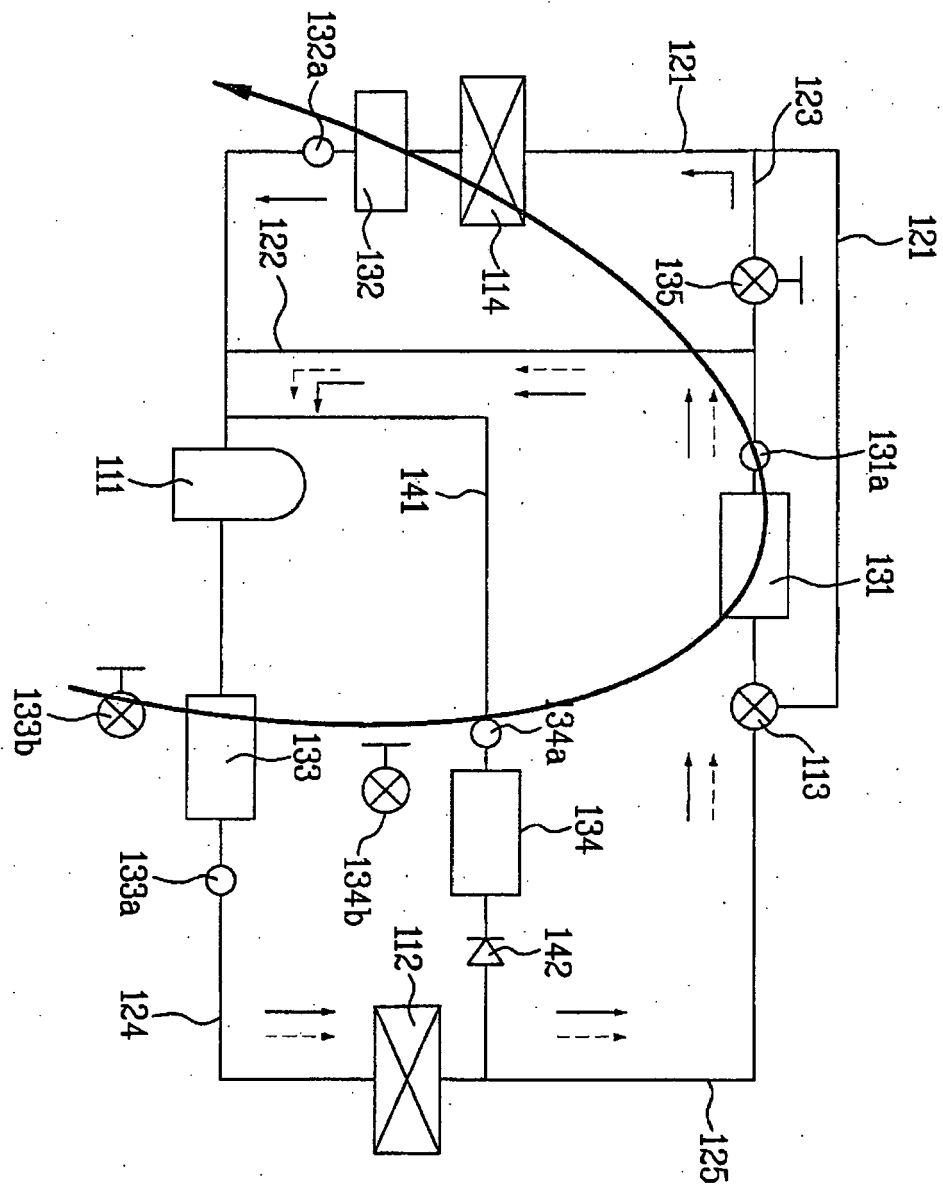


FIG. 2C

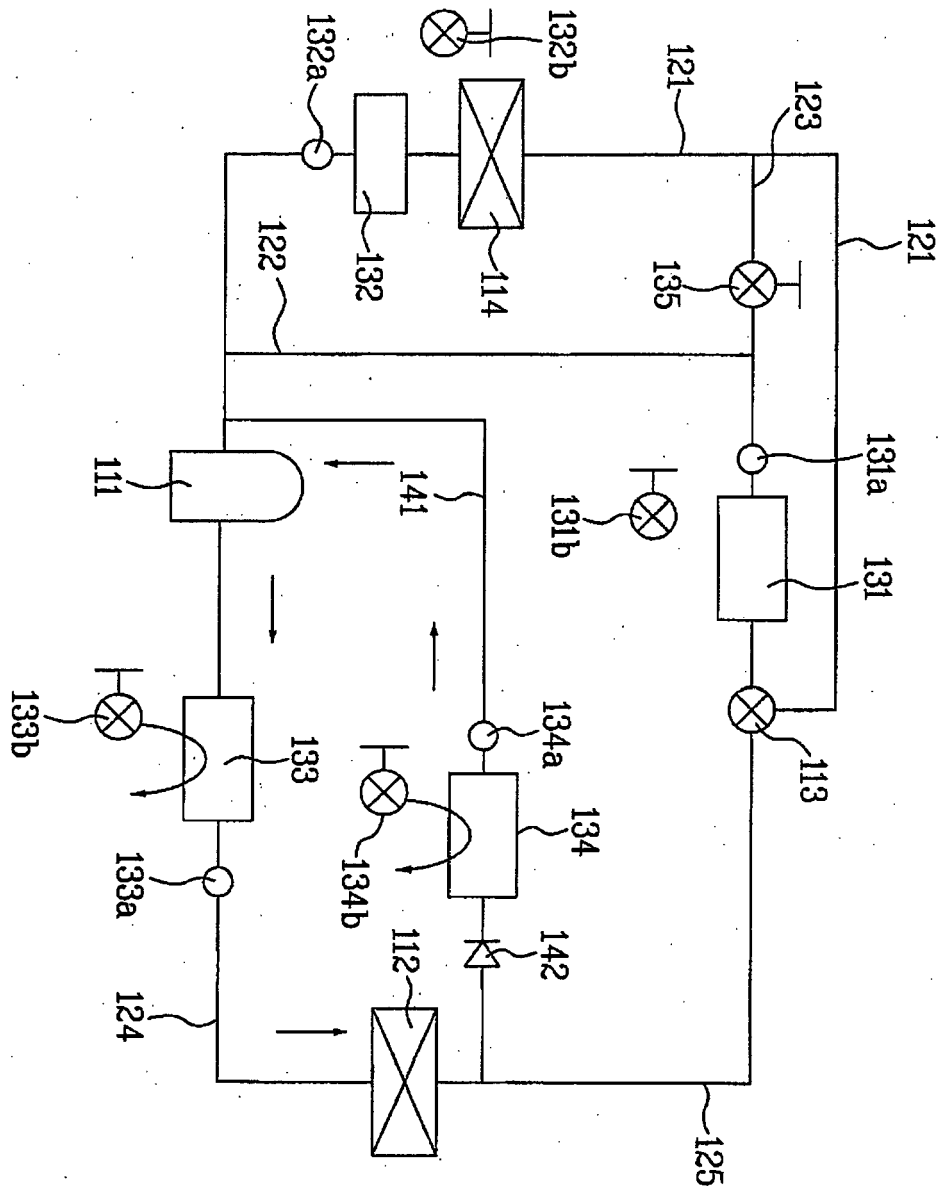


FIG. 3A

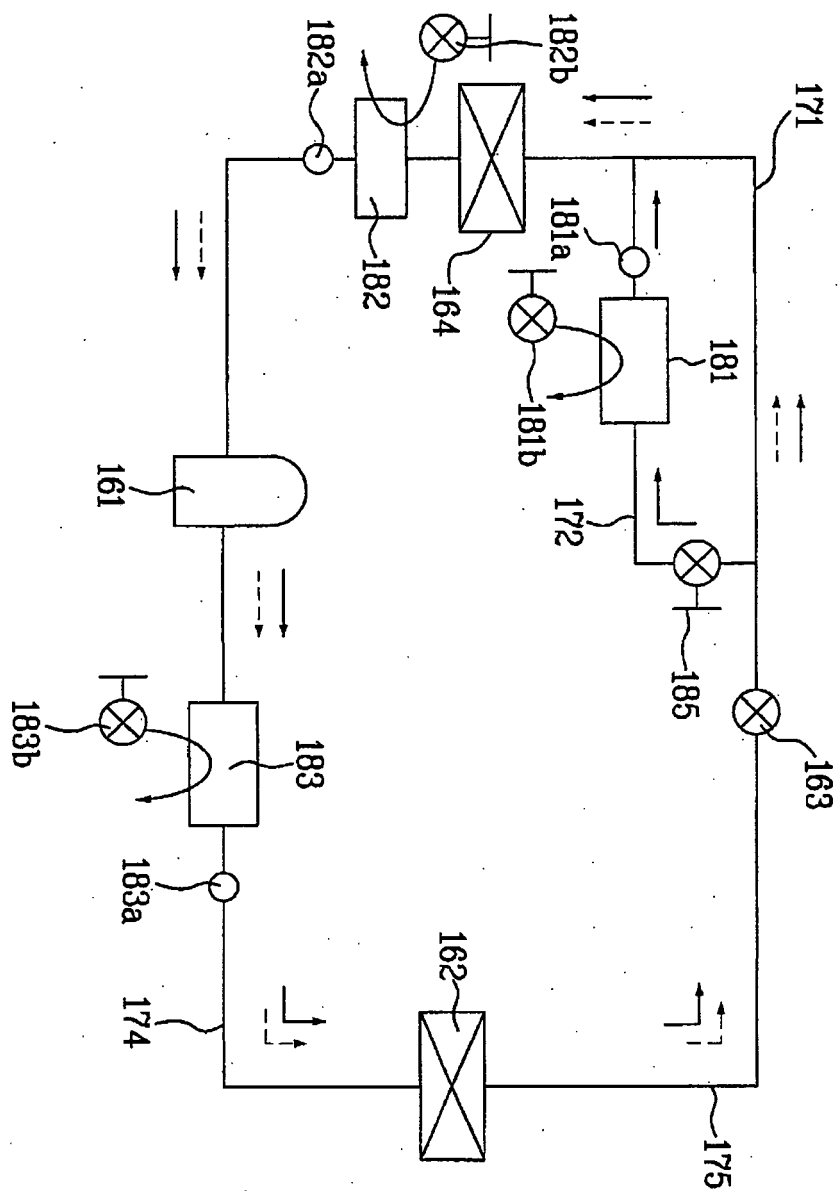


FIG. 3B

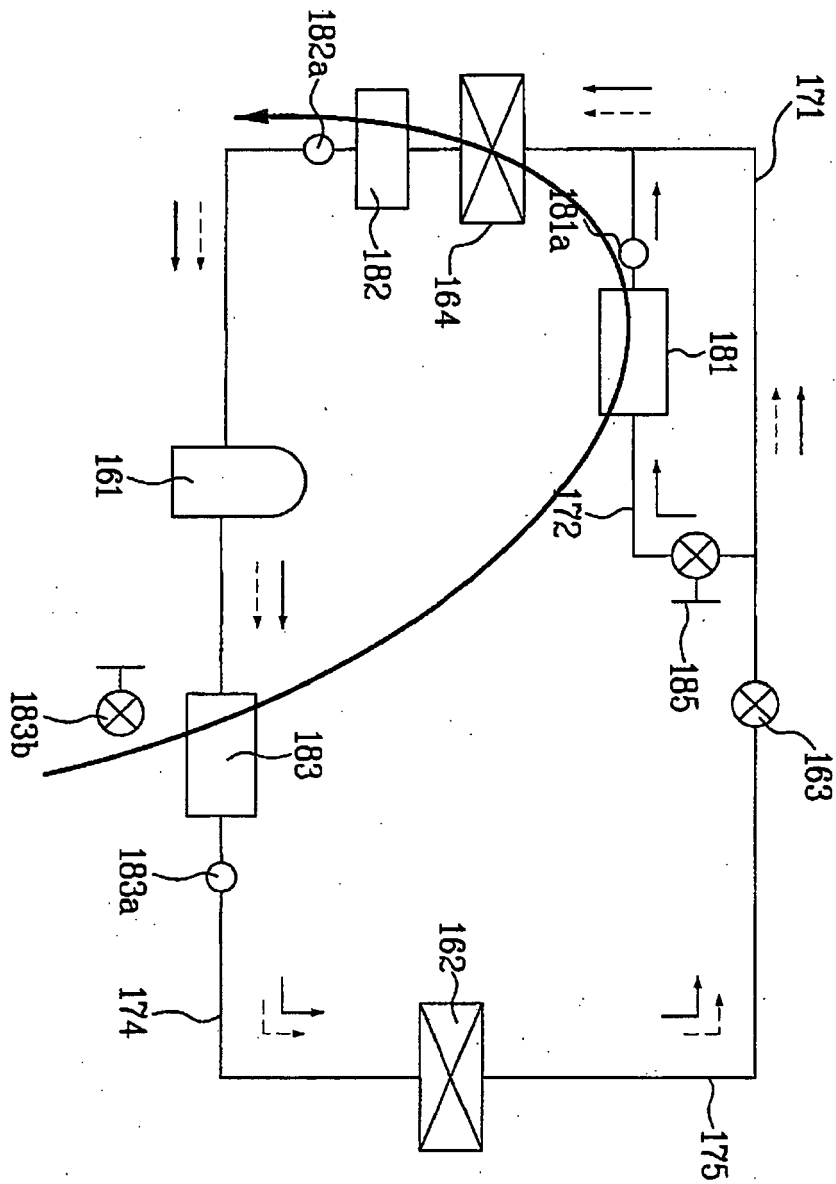


FIG. 4A

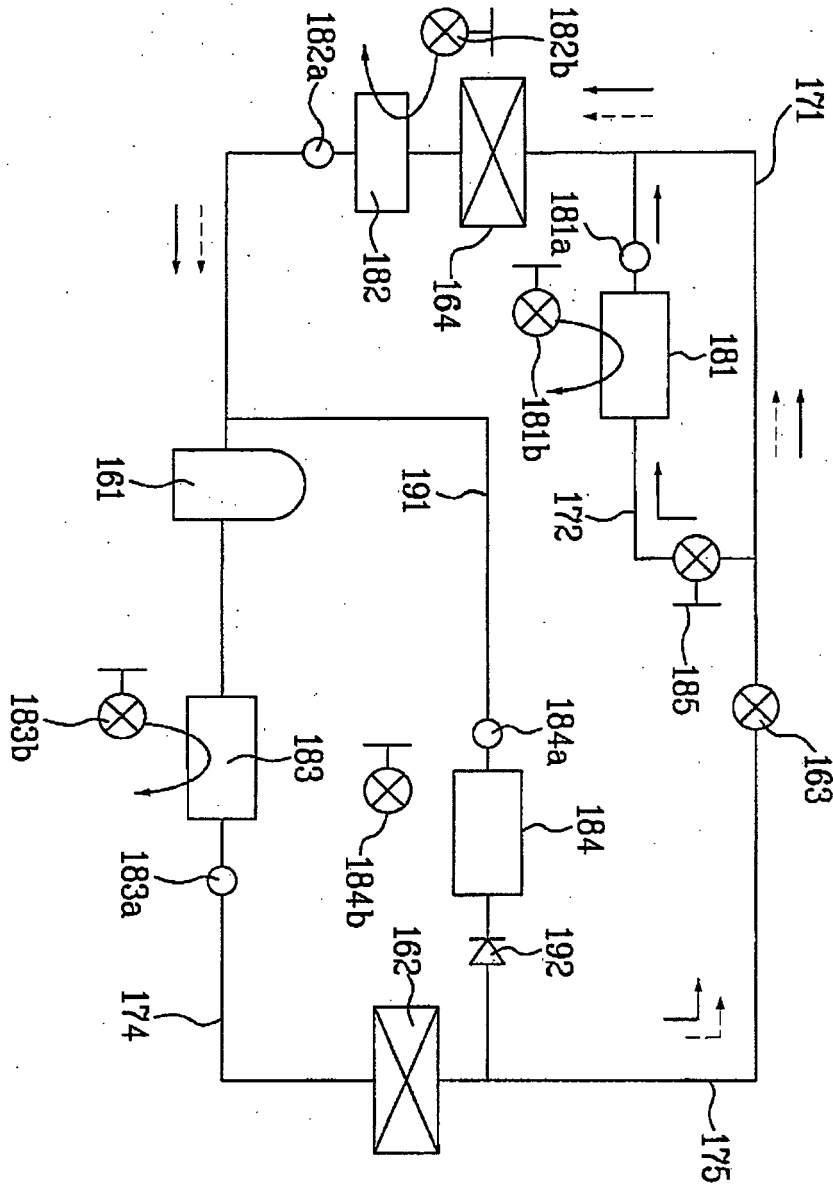


FIG. 4B

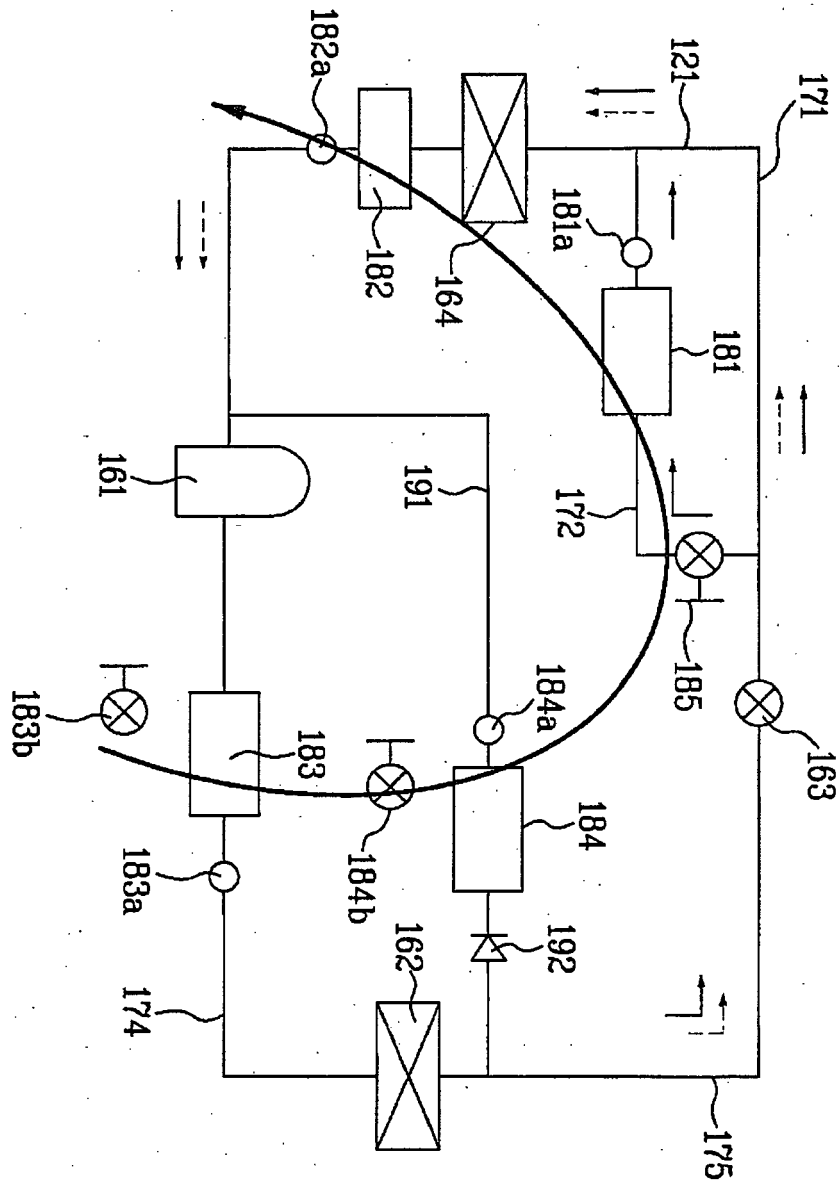


FIG. 4C

