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(57) A heat pump system which executes cooling and heating operations of an A2A indoor unit and cooling and heating operations and a hot water operation of an A2W indoor unit in a time division multiplexing (TDM) method, and a control method thereof. Further, the heat pump system solves shortage of a refrigerant during a heating operation of the A2A indoor unit or the A2W indoor unit

when the TDM method is used. Therefore, the heat pump system includes a control unit to alternately operate the A2A indoor unit or the A2W indoor unit, upon judging that a simultaneous operating condition of the A2A indoor unit or the A2W indoor unit is satisfied. The heat pump system further includes a refrigerant distribution unit to circulate a refrigerant selectively to the A2A indoor unit or the A2W indoor unit.

Description

BACKGROUND

1. Field

[0001] Embodiments relate to a heat pump system in which a plurality of indoor units is connected to an outdoor unit so as to cool or heat air in indoor spaces or to supply hot water, and a control method thereof.

2. Description of the Related Art

[0002] A heat pump system uses heat of a heat pump, including a compressor, an outdoor air exchanger, an expander, a water-refrigerant heat exchanger, and an indoor exchanger, to heat an indoor floor or to cool and heat indoor air.

[0003] In general, heat pump systems are divided into a system using an air to air heat pump (hereinafter, referred to as an "A2A heat pump") including a refrigerant pipe through which a cold or hot refrigerant passes and a fan generating air so as to cool or heat an indoor space, and a system using an air to water heat pump (hereinafter, referred to as an "A2W heat pump") to cool or heat an indoor space or to heat water stored in a water tank using a water pipe through which cold or hot water passes.

[0004] If the above two heat pumps are combined into one multi-functional product, a system to which heat recovery (HR) is applied is used so as to cool an indoor space or to supply hot water. Here, a separate unit to carry out conversion between a cooling operation and a heating operation is additionally used and thus raises manufacturing costs of the product, and a separate program for the HR is operated and thus increases complexity of the product. Further, the sum total of a capacity of the A2A heat pump and a capacity of the A2W heat pump becomes equal to a capacity of an outdoor unit, and thus the A2A heat pump and the A2W heat pump may not be installed in the same space or an outdoor unit having a greater capacity may be required.

SUMMARY

[0005] Therefore, it is an aspect to provide a heat pump system which executes cooling and heating operations of an A2A indoor unit and cooling and heating operations and a hot water operation of an A2W indoor unit through a time division multiplexing (TDM) method, if necessary, without any additional unit, and a control method thereof.

[0006] It is another aspect to provide a heat pump system which executes a preliminary heating operation to solve shortage of a refrigerant during a heating operation of an A2A indoor unit or an A2W indoor unit when a time division multiplexing (TDM) method is used, and a control method thereof.

[0007] Additional aspects will be set forth in part in the

description which follows and, in part, will be apparent from the description, or may be learned by practice of the invention.

[0008] In accordance with one aspect, a heat pump system includes an outdoor unit including an outdoor air heat exchanger, at least one first indoor unit including an indoor air heat exchanger, at least one second indoor unit including an indoor water-refrigerant heat exchanger, a refrigerant circulation pipe unit connected to the outdoor unit, the at least one first indoor unit, and the at least one second indoor unit to circulate a refrigerant, and a control unit controlling the at least one first indoor unit and the at least one second indoor unit so as to be alternately operated, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.

[0009] A capacity of the at least one first indoor unit and a capacity of the at least one second indoor unit may be equal to a capacity of the outdoor unit, or the sum total of the capacity of the at least one first indoor unit and the capacity of the at least one second indoor unit may be in the range of 50~130% of the capacity of the outdoor unit.

[0010] The outdoor unit may further include a variable capacity compressor having a variable capacity. The control unit may control the outdoor unit such that an output of the outdoor unit is not automatically varied but the outdoor unit is operated according to the maximum capacity of the operating one of the at least one first indoor unit and the at least one second indoor unit.

[0011] The heat pump system may further include a water circulation pipe unit to circulate water having exchanged heat with the refrigerant in the at least one second indoor unit, a hot water tank connected to the water circulation pipe unit, a first sub heater to heat the water circulation pipe unit, and a second sub heater to heat the hot water tank, and the control unit may execute a heating operation or a hot water operation of the at least one second indoor unit using at least one of the first sub heater and the second sub heater and control the outdoor unit so as to execute a cooling operation of the at least one first indoor unit, if the heating operation or the hot water operation of the at least one second indoor unit is requested during the cooling operation of the at least one first indoor unit.

[0012] The heat pump system may further include an input unit, through which an operation mode of the at least one first indoor unit and the at least one second indoor unit is input, and the control unit may control the at least one first indoor unit and the at least one second indoor unit so as to be alternately operated under the condition that the operation of the at least one first indoor unit or the at least one second indoor unit is limited to a cooling mode or a heating mode according to the cooling mode or the heating mode input through the input unit.

[0013] The control unit may control the at least one first indoor unit and the at least one second indoor unit so as to be operated in a hot water operation mode only, if the hot water operation mode is input through the input

unit. If the at least one first indoor unit is operating when the hot water operation mode is input through the input unit, the control unit may operate the at least one first indoor unit in a rapid cooling mode or a rapid heating mode to enable the at least one first indoor unit to reach a target temperature and then control the at least one first indoor unit and the at least one second indoor unit so as to be operated in the hot water operation mode only. Here, the control unit may stop the operation in the hot water operation mode, if a signal to stop the hot water operation mode is input through the input unit or water in a hot water tank reaches a hot water set temperature.

[0014] The control unit may simultaneously operate the at least one first indoor unit and the at least one second indoor unit, upon judging that the sum total of a capacity required by the at least one first indoor unit and a capacity required by the at least one second indoor unit is less than a capacity of the outdoor unit.

[0015] The control unit may preferentially operate any one of the at least one first indoor unit and the at least one second indoor unit, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied. Here, the control unit may preferentially operate the at least one first indoor unit.

[0016] The control unit may change the operation of the at least one first indoor unit into the operation of the at least one second indoor unit, upon judging that the at least one first indoor unit reaches a first target temperature during the preferential operation of the at least one first indoor unit or the at least one first indoor unit is operated for a first set time.

[0017] Further, the control unit may stop the operation of the at least one second indoor unit, upon judging that the at least one second indoor unit reaches a second target temperature during the operation of the at least one second indoor unit or the at least one second indoor unit is operated for a second set time.

[0018] The control unit may lower the first target temperature by a reference value, if the first target temperature and the second target temperature are equal, the at least one second indoor unit is not operated, and the number of on/off of the operation of the at least one first indoor unit reaches a designated number.

[0019] In accordance with another aspect, a control method of a heat pump system, which has an outdoor unit including an outdoor air heat exchanger, at least one first indoor unit including an indoor air heat exchanger, at least one second indoor unit including an indoor water-refrigerant heat exchanger, and a refrigerant circulation pipe unit connected to the outdoor unit, the at least one first indoor unit, and the at least one second indoor unit to circulate a refrigerant, includes alternately operating the at least one first indoor unit and the at least one second indoor unit, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.

[0020] Any one of the at least one first indoor unit and

the at least two indoor unit may be preferentially operated, upon judging that the simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied. Here, the at least one first indoor unit may be preferentially operated.

[0021] In accordance with another aspect, a heat pump system includes at least one first indoor unit including an indoor air heat exchanger and a first expander, at least one second indoor unit including an indoor water-refrigerant heat exchanger and a second expander, an outdoor unit including an outdoor air heat exchanger, a compressor, and a third expander, a refrigerant circulation pipe unit connected to the at least one first indoor unit, the at least one second indoor unit, and the outdoor unit to circulate a refrigerant, a refrigerant distribution unit to circulate the refrigerant selectively to the at least one first indoor unit and the at least one second indoor unit, and a control unit controlling the at least one first indoor unit and the at least one second indoor unit so as to be alternately operated, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.

[0022] The refrigerant distribution unit may include a four-way valve and check valves, or may include a three-way valve.

[0023] The control unit may execute a preliminary heating operation by driving the compressor, under the condition that the expander of one of the at least one first indoor unit and the at least one second indoor unit, a heating operation of which is executed, is closed and the expander of the other one of the at least one first indoor unit and the at least one second indoor unit is opened, before the heating operation of the one of the at least one first indoor unit and the at least one second indoor unit is executed.

[0024] In accordance with a further aspect, a control method of a heat pump system, which has at least one first indoor unit including an indoor air heat exchanger and a first expander, at least one second indoor unit including an indoor water-refrigerant heat exchanger and a second expander, an outdoor unit including an outdoor air heat exchanger, a compressor, and a third expander, a refrigerant circulation pipe unit connected to the at least one first indoor unit, the at least one second indoor unit, and the outdoor unit to circulate a refrigerant, and a refrigerant distribution unit to circulate the refrigerant selectively to the at least one first indoor unit and the at least one second indoor unit, includes executing a preliminary heating operation by driving the compressor, under the condition that the expander of one of the at least one first indoor unit and the at least one second indoor unit, a heating operation of which is executed, is closed and the expander of the other one of the at least one first indoor unit and the at least one second indoor unit is opened, before the heating operation of the one of the at least one first indoor unit and the at least one second indoor unit is executed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1 is a schematic view illustrating the overall configuration of a heat pump system in accordance with one embodiment;

FIG. 2 is a schematic view illustrating the overall configuration of a heat pump system in accordance with another embodiment;

FIG. 3 is a first detailed view of the heat pump system of FIG. 1;

FIG. 4 is a second detailed view of the heat pump system of FIG. 1;

FIG. 5 is a detailed view of the heat pump system of FIG. 2;

FIG. 6 is a block diagram illustrating an operation of a control unit of a heat pump system in accordance with one embodiment;

FIG. 7 is a detailed view illustrating a first preliminary heating operation of the heat pump system in accordance with the embodiment;

FIG. 8 is a detailed view illustrating a first heating operation of the heat pump system in accordance with the embodiment;

FIG. 9 is a detailed view illustrating a second preliminary heating operation of the heat pump system in accordance with the embodiment;

FIG. 10 is a detailed view illustrating a second heating operation of the heat pump system in accordance with the embodiment;

FIG. 11 is a detailed view illustrating a first cooling operation of the heat pump system in accordance with the embodiment;

FIG. 12 is a detailed view illustrating a second cooling operation of the heat pump system in accordance with the embodiment;

FIG. 13 is a detailed view illustrating a second heating operation of the heat pump system in accordance with the embodiment using a sub heater;

FIG. 14 is a flow chart illustrating a time division multiplexing (TDM) alternating operation of the heat

pump system in accordance with the embodiment;

FIG. 15 is a flow chart illustrating preferential execution of one operation during the TDM alternating operation of FIG. 14;

FIG. 16 is a flow chart illustrating a control method of the heat pump system, if set temperatures of a first indoor unit and a second indoor unit are equal;

FIG. 17 is a flow chart illustrating preferential execution of the hot water operation;

FIG. 18 is a flow chart illustrating a simultaneous operation of heat pumps in accordance with one embodiment; and

FIG. 19 is a graph illustrating input and output flows illustrating an alternating operation of the heat pumps in accordance with the embodiment.

DETAILED DESCRIPTION

[0026] Reference will now be made in detail to the embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0027] FIG. 1 is a schematic view illustrating the overall configuration of a heat pump system in accordance with one embodiment.

[0028] A heat pump system 1 in accordance with this embodiment includes an outdoor unit 10, a refrigerant distribution unit 20, a first indoor unit 30, a second indoor unit 40, a heating load 50, and a hot water tank 60. The heat pump system 1 further includes a refrigerant circulation pipe unit 11 formed in a closed loop via the outdoor unit 10, the refrigerant distribution unit 20, the first indoor unit 30, and the second indoor unit 40.

[0029] The refrigerant circulation pipe unit 11 includes refrigerant circulation pipes 11 a and 11 b connecting the outdoor unit 10 and the refrigerant distribution unit 20, a refrigerant circulation pipe 11 c connecting the refrigerant distribution unit 20 and the first indoor unit 30, and refrigerant circulation pipes 11 d and 11 e connecting the second indoor unit 40 and the refrigerant distribution unit 20.

[0030] Further, a water circulation pipe unit 17 is connected to the second indoor unit 40, and is connected to the heating load 50 and the hot water tank 60. The water circulation pipe unit 17 is also formed in a closed loop. A detailed structure of the water circulation pipe unit 17 will be described later.

[0031] FIG. 2 is a schematic view illustrating the overall configuration of a heat pump system in accordance with another embodiment.

[0032] In FIG. 2, a heat pump system 2 in accordance with this embodiment includes an outdoor unit 12 having five connection pipes, and the refrigerant distribution unit 20 and the second indoor unit 40 of FIG. 1 are installed

within the outdoor unit 12. Other structures of FIG. 2 are the same as those of FIG. 1, and a detailed description thereof will thus be omitted.

[0033] FIG. 3 is a first detailed view of the heat pump system of FIG. 1. With reference to FIG. 3, the structure and operation of the heat pump system 1 in accordance with one embodiment will be described in detail.

[0034] The outdoor 10 includes a compressor 14, a first four-way valve 15, a third expander 16, a third heat exchanger 18, and two connection valves 13a and 13b.

[0035] The compressor 14 serves to compress a refrigerant from a low-temperature and low-pressure gaseous state to a high-temperature and high-pressure gaseous state, and may include a variable capacity compressor having a compression capacity which is variable according to the loads 30 and 40.

[0036] Further, the compressor 14 may include an inverter compressor having a compression capacity which is variable according to input frequencies, or a combination of a plurality of constant speed compressors, each of which has a constant compression capacity. The compressor 14 is connected to the first four-way valve 15 through the refrigerant circulation pipe unit 11.

[0037] The first four-way valve 15 is a valve which may be opened and closed in four directions, and serves to guide the refrigerant having passed through the refrigerant circulation pipe unit 11 in two directions. As shown in FIG. 3, the refrigerant having passed through the compressor 14 is transmitted to the refrigerant distribution unit 20 or the third heat exchanger 18 through the refrigerant circulation pipe unit 11.

[0038] The expander 16 is a kind of a variable expansion device, which expands or intercepts the refrigerant having passed through the third heat exchanger 18 or the load 30 or 40, and includes an electronic expansion valve (EEV), an opening value of which is variable, so as to adjust an amount of the refrigerant. The expander 16 is connected to the loads 30 and 40 and the third heat exchanger 18 through the refrigerant circulation pipe unit 11.

[0039] The third heat exchanger 18 is a kind of the above-stated A2A heat exchanger, and serves to exchange heat between the refrigerant having passed through the compressor 14 or the expander 16 and outdoor air. The third heat exchanger 18 may include a fan (not shown) to exchange heat between the refrigerant and outdoor air.

[0040] The connection valves 13a and 13b serve to connect the refrigerant circulation pipes 11 a and 11 b, connecting the outdoor unit 10 and the refrigerant distribution unit 20, to the outdoor unit 10.

[0041] The refrigerant distribution unit 20 includes a second four-way valve 22, three check valves 23, 24, and 25, a capillary tube 26, and connection valves 13d~13h.

[0042] The second four way valve 22 is opened and closed so as to circulate the refrigerant passing through the refrigerant circulation pipe unit 11 selectively toward

the first indoor unit 30 and the second indoor unit 40. That is, if it is desired that the refrigerant be circulated toward the first indoor unit 30, although this is not shown in FIG. 3, a first valve 22a and a second valve 22b are communicated with each other to circulate the refrigerant toward the first indoor unit 30, and a third valve 22c and a fourth valve 22d are communicated with each other. On the other hand, if it is desired that the refrigerant be circulated toward the second indoor unit 40, the first valve 22a and the fourth valve 22d are communicated with each other, and the second valve 22b and the third valve 22c are communicated with each other. Detailed operations of respective cooling and heating cycles will be described later.

[0043] The three check valves 23, 24, and 25 serve to enable the refrigerant to flow only in one direction, and the capillary tube 26 serves to expand the refrigerant.

[0044] The first indoor unit 30 is a heat pump to cool or heat indoor air, and includes a first heat exchanger 32 which is a kind of an A2A heat exchanger, i.e., outdoor air heat exchanger, a first expander 34, and a connection valve 13i. The first heat exchanger 32 exchanges heat between the cold or hot refrigerant passing through the refrigerant circulation pipe unit 11 and air, thus cooling or heating indoor air. The first expander 34 executes the same role as the third expander 18.

[0045] The second indoor unit 40 is a heat pump to cool or heat water in the water circulation pipe unit 17, and includes a second heat exchanger 42 which is a kind of an A2W heat exchanger, i.e., water-refrigerant heat exchanger, a second expander 44, and a connection valve 13j. The second heat exchanger 42 exchanges heat between the cold or hot refrigerant passing through the refrigerant circulation pipe unit 11 and the water in the water circulation pipe unit 17, thus cooling or heating the water in the water circulation pipe unit 17. The second expander 44 executes the same role as the third expander 18.

[0046] The water circulation pipe unit 17, through which water heated or cooled through the second heat exchanger 42 is circulated, is again connected to the heating load 50 and the hot water tank 60. The heating load 50 includes a fourth heat exchanger 52 to exchange heat between the water in the water circulation pipe unit 17 and air, and the hot water tank 60 includes a fifth heat exchanger 62 to exchange heat between the water in the water circulation pipe unit 17 and the water stored in the hot water tank 60. Further, a three-way valve (not shown) is installed at a point where the water circulation pipe unit 17 is branched off into the heating load 50 and the hot water tank 60, and is opened and closed toward a desired load under the control of a control unit 45 which will be described later.

[0047] FIG. 4 is a second detailed view of the heat pump system of FIG. 1. The heat pump system 1 of FIG. 4 has the same structure as that of the heat pump system 1 of FIG. 3 except that a three-way valve 21 is installed in a refrigerant distribution unit 20' instead of the second

four way valve 22. If the three-way valve 21 is used, when the first indoor unit 30 and the second indoor unit 40 are alternately operated, circulation of the refrigerant toward the refrigerant circulation pipe unit 11 at the indoor unit which is not operated is blocked.

[0048] FIG. 5 is a detailed view of the heat pump system of FIG. 2. As described above, the heat pump system 2 includes the outdoor unit 12 having the five connection pipes, 13a, 13b, 13k, 13l, and 13m, and the refrigerant distribution unit 20 and the second indoor unit 40 are installed within the outdoor unit 12. That is, the outdoor unit 12 of FIG. 5 is the integral outdoor unit 12 in which the second indoor unit 40, i.e., a hydro unit, is installed. The heat pump system 2 has a structure which is slightly different from that of the heat pump system 1, and thus the heat pump system 1 is exemplarily described hereinafter.

[0049] FIG. 6 is a block diagram illustrating an operation of a control unit of a heat pump system in accordance with one embodiment.

[0050] The heat pump system 1 includes a control unit 45 and an input unit 46. The input unit 46 may be a device, such as a remote controller, or may be installed integrally with the control unit 45. The input unit 46 enables a user to input an operation mode or a set temperature of the heat pump system 1.

[0051] The control unit 45 controls the first four-way valve 15, the second four-way valve 22, the first expander 34, the second expander 44, and the third expander 16 according to data input through the input unit 46. Although the control unit 45 may be installed in the outdoor unit 10, the control unit 45 is generally installed in the first indoor unit 30 or the second indoor unit 40 close to the user. Here, heating and cooling operation cycles of the heat pump system 1 based on the operation of the control unit 45 will be described in detail.

[0052] FIG. 7 is a detailed view illustrating a first preliminary heating operation of the heat pump system in accordance with the embodiment.

[0053] The heat pump system 1 in accordance with this embodiment is controlled such that the first indoor unit 30 and the second indoor unit 40 are alternately operated using a time division multiplexing (TDM) method, which will be described with reference to FIGS. 14 to 19. Such an alternating operation will be described in detail with reference to FIGS. 14 to 19, and a preliminary heating operation to prevent shortage of an amount of the refrigerant during the heating operation due to trapping of the refrigerant within a stopped indoor unit, if the first indoor unit 30 or the second indoor unit 40 executes the heating operation, will be described in detail now.

[0054] Here, "the preliminary heating operation" means a refrigerant recovery operation in which the refrigerant trapped in the stopped indoor unit is recovered before the heating operation. With reference to FIG. 7, the first preliminary heating operation, i.e., a preliminary heating operation of the indoor unit 30, will be described.

[0055] Although this will be described later, the time

division multiplexing (TDM) method is a method in which, if the first indoor unit 30 and the second indoor unit 40 are operated, the first indoor unit 30 and the second indoor unit 40 are alternately operated. Therefore, as shown in a refrigerant cycle circuit shown in FIG. 7, when the first valve 22a and the second valve 22b of the second four-way valve 22 are communicated with each other and the third valve 22c and the fourth valve 22d of the second four-way valve 22 are communicated with each other, and then the compressor 14 is driven under the condition that the first expander 34 is opened and the second expander 44 is closed, the refrigerant is accumulated and trapped in a oval second region 38 shown in a dotted line. This happens because the second expander 44 is closed and thus the refrigerant does not move to the right side of the expander 44, and the refrigerant does not move through the refrigerant circulation pipe unit 11 where the check valve 24 is located due to the pressure of the refrigerant discharged from the compressor 14.

[0056] Therefore, the trapping of the refrigerant may generate shortage of the amount of the refrigerant during the heating operation. In order to reduce the trapping of the refrigerant, the second expander 44 is not completely closed, but is opened at more than a designated opening value. However, although the second expander 44 is opened at more than the designated opening value, the indoor unit 30 may not have 100% output, and thus in case of an operation requiring 100% output, problems are generated.

[0057] Therefore, in order to remove the trapping of the refrigerant, the preliminary heating operation which is the refrigerant recovery operation to completely recover the trapped refrigerant is executed. FIG. 7 illustrates a flow of the refrigerant, if the first preliminary heating operation of the first indoor unit 30 is executed before the heating operation.

[0058] During the first preliminary heating operation of the first indoor unit 30, the first valve 22a and the second valve 22b of the second four-way valve 22 are communicated with each other and the third valve 22c and the fourth valve 22d of the second four-way valve 22 are communicated with each other, and then the compressor 14 is driven under the condition that the first expander 34 is closed and the second expander 44 is opened.

[0059] When the compressor 14 is driven, the refrigerant trapped in the second region 38 sequentially passes through the refrigerant circulation pipe 11 e, the refrigerant circulation pipe 11 b, the expander 16, the third heat exchanger 18, the compressor 14, and the second four-way valve 22 due to the pressure of the compressor 14, and then is accumulated in a first region 36. That is, since the first expander 34 is closed, all of the refrigerant in the refrigerant circulation pipe unit 11 is temporarily accumulated in the first region 36, and all of the refrigerant accumulated in the second region 38 is collected in the first region 36. A heating operation is executed after such a refrigerant recovery operation, and a detailed description thereof will be given with reference to FIG. 8.

[0060] FIG. 8 is a detailed view illustrating a first heating operation of the heat pump system in accordance with the embodiment.

[0061] When all of the refrigerant trapped in the second region 38 is recovered in the first region 36 by the first preliminary heating operation of FIG. 7, the control unit 45 opens the first expander 34 and closes the second expander 44 and thus executes the heating operation of the first indoor unit 30. At this time, since none of the refrigerant is trapped in the second region 38 and the circulated refrigerant is not introduced into the second region 38 by the check valve 24 and the second expander 44, the heating operation of the first indoor unit 30 may be executed at 100% output. Since the heating operation is executed, the refrigerant in a high-temperature and high-pressure state generated from the compressor 14 exchanges heat with air through the first heat exchanger 32 via the first four-way valve 15 and the second four-way valve 22, thus being changed into a low-temperature and high-pressure state. The refrigerant in the low-temperature and high-pressure state is changed into a low-temperature and low-pressure state through the first expander 34, the third expander 16, and the third heat exchanger 18, and then is again introduced into the compressor 14. The heating operation of the first indoor unit 30 is executed through such a cycle.

[0062] FIG. 9 is a detailed view illustrating a second preliminary heating operation of the heat pump system in accordance with the embodiment, and FIG. 10 is a detailed view illustrating a second heating operation of the heat pump system in accordance with the embodiment.

[0063] FIGS. 9 and 10 respectively illustrate flows of the refrigerant during the second preliminary heating operation and the heating operation of the second indoor unit 40. In the second preliminary heating operation and the heating operation of the second indoor unit 40, the communication direction of the second four-way valve 22 and the control direction of the first expander 34 and control of the second expander 44 are changed so as to be opposite to the directions in the first preliminary heating operation and the heating operation of the first indoor unit 30, and a detailed description thereof will thus be omitted.

[0064] FIG. 11 is a detailed view illustrating a first cooling operation of the heat pump system in accordance with the embodiment, and FIG. 12 is a detailed view illustrating a second cooling operation of the heat pump system in accordance with the embodiment.

[0065] As shown in FIGS. 11 and 12, a preliminary cooling operation is not executed before a cooling operation. During the cooling operation, the compressor 14 discharges the refrigerant in the direction opposite to the discharging direction of the refrigerant from the compressor 14 during the heating operation. Then, the compressor 14 is in a low-pressure state due to refrigerant suction force, and thus the refrigerant naturally moves to the compressor 14 through the refrigerant circulation pipe unit 11

where the check valve 24 is located. That is, the refrigerant is circulated through the refrigerant circulation pipe unit 11.

[0066] As described above, the refrigerant in the high-temperature and high-pressure state generated from the compressor 14 without the refrigerant recovery operation is changed to a low-temperature and high-pressure state through the third heat exchanger 18, is changed to a low-temperature and low-pressure state through the third expander 16 and the first expander 34, and then exchanges heat with air through the first heat exchanger 32 and thus is changed to a high-temperature and low-pressure state.

[0067] FIG. 12 illustrates the cooling operation of the second indoor unit 40, i.e., the second cooling operation. The second cooling operation of the second indoor unit 40 shown in FIG. 12 differs from the first cooling operation of the first indoor unit 30 shown in FIG. 11 only in that the second four-way valve 22, and the valves of the first expander 34 and the second expander 44 during the second cooling operation of the second indoor unit 40 are operated in directions opposite to the directions during the first cooling operation of the first indoor unit 30, and a detailed description thereof will thus be omitted.

[0068] FIG. 13 is a detailed view illustrating a second heating operation of the heat pump system in accordance with the embodiment using a sub heater.

[0069] FIG. 13 illustrates that the heat pump system shown in FIG. 8 further includes a first sub heater 43 installed at the water circulation pipe unit 17 of the second heat exchanger 42 of the second indoor unit 40 and a second sub heater 64 installed in the hot water tank 60.

[0070] During the heating operation of FIG. 13, at least one of the first sub heater 43 and the second sub heater 64 is operated if an output of the outdoor unit 10 is smaller than an output required during the heating operation due to a problem, such as a hot water operation of the hot water tank 60.

[0071] Further, although this is not shown in FIG. 13, if a hot water operation mode of the hot water tank 60 is input through the input unit 46 during the cooling operation of the first indoor unit 30 under the condition that the first valve 22a and the second valve 22b of the second four-way valve 22 are communicated with each other and the third valve 22c and the fourth valve 22d of the second four-way valve 22 are communicated with each other, the hot water operation of the hot water tank 60 may be executed using at least one of the first sub heater 43 and the second sub heater 64 while continuously executing the cooling operation of the first indoor unit 30 using the outdoor unit 10.

[0072] Hereinafter, a method of controlling an alternating operation of the first indoor unit 30 and the second indoor unit 40 through the TDM method using the heat pump system 1 having the above-described structure will be described in detail.

[0073] FIG. 14 is a flow chart illustrating a time division multiplexing (TDM) alternating operation of the heat pump system in accordance with the embodiment, and

FIG. 15 is a flow chart illustrating preferential execution of one operation during the TDM alternating operation of FIG. 14.

[0074] In the heat pump system 1 in accordance with one embodiment, if it is judged that an operating condition of any one of the first indoor unit 30 and the second indoor unit 40 is satisfied, the first indoor unit 30 or the second indoor unit 40 is operated at 100% output. Here, a capacity of the first indoor unit 30 and a capacity of the second indoor unit 40 are equal to that of the outdoor unit 10. Further, the sum total of the capacity of the first indoor unit 30 and the capacity of the second indoor unit 40 may be in the range of 50~130% of the capacity of the outdoor unit 10 according to design specifications. Further, the first indoor unit 30 and the second indoor unit 40 may have various capacities.

[0075] As shown in FIG. 14, it is judged whether or not a simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied (operation 100), and the first indoor unit 30 and the second indoor unit 40 are alternately operated through the TDM method if it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied (operation 102). This will be described in detail with reference to FIG. 15.

[0076] FIG. 15 illustrates preferential execution of the operation of the first indoor unit 30 during the alternating operation of the first indoor unit 30 and the second indoor unit 40. The reason for the preferential execution of the operation of the first indoor unit 30 is as follows.

[0077] That is, if a load requirement is given by a user under the condition that heat accumulation of a load is low, as in a house, the first indoor unit 30 rapidly reaching performance is preferentially operated so as to satisfy the user, and then the second indoor unit 30 slowly reaching performance is alternately operated, thereby changing the operation of the heat pump system from convective cooling or heating to radiant cooling or heating.

[0078] With reference to FIG. 15, the control unit 45 judges whether or not a simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied (operation 104). If it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied, the control unit 45 operates the first indoor unit (operation 106). The control unit 45 judges whether or not an operation completing condition of the first indoor unit 30 is satisfied during the cooling or heating operation of the first indoor unit 30 (operation 108). The control unit 45 continuously executes the operation of the first indoor unit 30, if it is judged that the operation completing condition of the first indoor unit 30 is not satisfied, and stops the operation of the first indoor unit 30 and operates the second indoor unit 40, if it is judged that the operation completing condition of the first indoor unit 30 is satisfied (operation 110).

[0079] Here, the operation completing condition of the first indoor unit 30 may include whether or not the first indoor unit 30 reaches a first target temperature, i.e., a

target set temperature of the first indoor unit 30, or whether or not the first indoor unit 30 is operated for a first set time, i.e., the minimum or maximum operating time of the first indoor unit 30.

[0080] The control unit 45 judges whether or not an operation completing condition of the second indoor unit 40 is satisfied during the operation of the second indoor unit 40 (operation 114). The control unit 45 continuously executes the operation of the second indoor unit 40, if it is judged that the operation completing condition of the second indoor unit 40 is not satisfied, and stops the operation of the second indoor unit 40, if it is judged that the operation completing condition of the second indoor unit 40 is satisfied (operation 116).

[0081] The operation completing condition of the second indoor unit 40 may also include whether or not the second indoor unit 40 reaches a second target temperature, i.e., a target set temperature of the second indoor unit 40, or whether or not the second indoor unit 40 is operated for a second set time i.e., the minimum or maximum operating time of the second indoor unit 40.

[0082] Here, the reason why the first set time and the second set time, i.e., the minimum or maximum operating times, are used as the operation completing conditions of the first and second indoor units 30 and 40 is to prevent frequent operation change between the first indoor unit 30 and the second indoor unit 40 and to prevent failure to satisfy the load of the second indoor unit 2.

[0083] If it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is not satisfied, the control unit 45 judges whether or not an operating condition of any one of the first indoor unit 30 and the second indoor unit 40 is satisfied (operation 118). If it is judged that an operating condition of any one of the first indoor unit 30 and the second indoor unit 40 is satisfied, the control unit 45 operates the first indoor unit 30 or the second indoor unit 40 (operation 120).

[0084] The control unit 45 judges whether or not the operation completing condition of the first indoor unit 30 or the second indoor unit 40 is satisfied during the operation of the first indoor unit 30 or the second indoor unit 40 (operation 122). The control unit 45 continuously executes the operation of the first indoor unit 30 or the second indoor unit 40, if it is judged that the operation completing condition of the first indoor unit 30 or the second indoor unit 40 is not satisfied, and stops the operation of the first indoor unit 30 or the second indoor unit 40, if it is judged that the operation completing condition of the first indoor unit 30 or the second indoor unit 40 is satisfied (operation 124).

[0085] The operation completing condition of the first indoor unit 30 or the second indoor unit 40 may include whether or not the first indoor unit 30 or the second indoor unit 40 reaches the first target temperature or the second target temperature, or whether or not the hot water operation mode is input, which will be described later.

[0086] FIG. 16 is a flow chart illustrating a control meth-

od of the heat pump system, if set temperatures of the first indoor unit and the second indoor unit are equal.

[0087] That is, as shown in 15, if it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied, the first indoor unit 30 and the second indoor unit 40 are alternately operated through the TDM method. However, when target set temperatures of the first indoor unit 30 and the second indoor unit 40 input through the input unit 46 are equal, if the operation completing condition of the first indoor unit 30 is satisfied, the operation completing condition of the second indoor unit 40 is also satisfied, and thus the second indoor unit 40 is not operated and is stopped. In this case, only the first indoor unit 30 is continuously switched on and off, and the stoppage of the second indoor unit 40 is maintained. If the above state is continued, the target set temperature of the first indoor unit 30 is forcibly lowered by 1 to 2 °C, and thereby the second indoor unit 40 is operated. FIG. 16 illustrates such a method.

[0088] That is, if the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied and thus the first indoor unit is preferentially operated and then the operation completing condition of the first indoor unit 30 is satisfied and thus the operation of the first indoor unit 30 is stopped (operation 110), as shown in FIG. 15, the control unit 45 judges whether or not the target set temperatures of the first indoor unit 30 and the second indoor unit 40 are equal (operation 126). Here, if it is judged that the target set temperatures of the first indoor unit 30 and the second indoor unit 40 are not equal, the process is returned to operation 112 of FIG. 15 and then the operation of the first indoor unit 40 is restarted.

[0089] On the other hand, if it is judged that the target set temperatures of the first indoor unit 30 and the second indoor unit 40 are equal, the target set temperature of the first indoor unit 30 is lowered by a designated value (operation 128). Thereby, the operating condition of the second indoor unit 40 is satisfied under the condition that the operation completing condition of the first indoor unit 30 is satisfied, and thus the second indoor unit 40 is operated.

[0090] FIG. 17 is a flow chart illustrating preferential execution of the hot water operation.

[0091] The heat pump system 1 in accordance with one embodiment executes the TDM alternating operation, if it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit is satisfied. However, if a temporary excessive hot water requirement is input, the heat pump system 1 may ignore the TDM alternating operation and preferentially execute the hot water operation. With reference to FIG. 17, the preferential execution of the hot water operation will be described as follows,

[0092] The control unit 45 judges whether or not a hot water operation mode is input (operation 130). If it is judged that the hot water operation mode is input, the

control unit 45 judges whether or not a hot water set temperature is more than a critical temperature (operation 132). Only if it is judged that the hot water set temperature is more than the critical temperature, the hot water operation is preferentially executed so as to prevent unnecessary mode change.

[0093] If it is judged that the hot water set temperature is more than the critical temperature, the control unit 45 stops the TDM alternating operation, and preferentially executes the hot water operation (operation 134). The control unit 45 judges whether or not the heat pump system 1 reaches the hot water set temperature during the hot water operation (operation 136).

[0094] The control unit 45 continuously executes the hot water operation, if it is judged that the heat pump system 1 does not reach the hot water set temperature, and stops the hot water operation, if it is judged that the heat pump system 1 reaches the hot water set temperature (operation 138).

[0095] The preferential execution of the hot water operation may be carried out only during the TDM alternating operation, or may be also carried out during the individual operation of the first indoor unit 30 or the second indoor unit 40.

[0096] FIG. 18 is a flow chart illustrating a simultaneous operation of heat pumps in accordance with one embodiment.

[0097] The heat pump system 1 in accordance with one embodiment of the present invention basically executes the TDM alternating operation, if it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit is satisfied. However, if the sum total of capacities required by the first indoor unit 30 and the second indoor unit 40 is less than the maximum capacity supplyable by the outdoor unit 10 due to a required capacity of a load, the heat pump system 1 may simultaneously operate the first indoor unit 30 and the second indoor unit 40.

[0098] That is, the control unit 45 judges whether or not the sum total of capacities required by the first indoor unit 30 and the second indoor unit 40 is less than the maximum capacity of the outdoor unit 10 (operation 140). If it is judged that the sum total of capacities required by the first indoor unit 30 and the second indoor unit 40 is more than the maximum capacity of the outdoor unit 10, the control unit 45 executes the TDM alternating operation (operation 144).

[0099] However, if it is judged that the sum total of capacities required by the first indoor unit 30 and the second indoor unit 40 is less than the maximum capacity of the outdoor unit 10, the control unit 45 simultaneously operates the first indoor unit 30 and the second indoor unit (operation 142).

[0100] FIG. 19 is a graph of input and output flows illustrating an alternating operation of the heat pumps in accordance with the embodiment.

[0101] Hereinafter, an operation of the first indoor unit 30 and an operation of the second indoor unit 40 based

on a signal requesting the operation of the first indoor unit 30 and a signal requesting the operation of the second indoor unit 40 of FIG. 19 will be described.

[0102] In a section (a), the signal requesting the operation of the second indoor unit 40 is input, and thus the second indoor unit 40 is operated. During the operation of the second indoor unit 40, in a section (b), the signal requesting the operation of the first indoor unit 30 is input, and thus the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied. However, since the first indoor unit 30 needs to be preferentially operated, the first indoor unit 30 is operated and the operation of the second indoor unit 40 is stopped.

[0103] Although the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is the same even when the heat pump system enters a section (c) after the section (b), since the maximum operating time of the first indoor unit 30 is set to a time corresponding to the length of the section (b), the operation of the first indoor unit 30 is stopped at the moment when the heat pump system enters the section (c), and then the second indoor unit 40 is operated.

[0104] Although the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is the same even when the heat pump system enters a section (d) after the section (c), since the maximum operating time of the second indoor unit 40 is set to a time corresponding to the length of the section (c), the operation of the second indoor unit 40 is stopped at the moment when the heat pump system enters the section (d), and then the first indoor unit 30 is operated.

[0105] When the heat pump system enters a section (e) after the section (d), the signal requesting the operation of the first indoor unit 30 disappears, and thus the operation of the first indoor unit 30 is stopped and the second indoor unit 40 is operated.

[0106] When the heat pump system enters a section (f) after the section (e), the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied again and the operation of the first indoor unit 30 is preferred, and thus the first indoor unit 30 is operated and the operation of the second indoor unit 40 is stopped.

[0107] Next sections are carried out by the above-described method, and a detailed description thereof will thus be omitted.

[0108] Further, although this is not shown in the drawings, if the compressor 14 of the outdoor unit 10 is a variable capacity compressor having a compression capacity which is variable, such as an inverter, an output of the outdoor unit 10 is automatically adjusted due to a difference between a set temperature and a current temperature. However, in order to smoothly execute the operation through the TDM method, the control unit 45 ignores the automatic output control, and operates the outdoor unit 10 according to the maximum capacity of the operating indoor unit 30 or 40, thereby rapidly executing the heating or cooling operation.

[0109] Further, the TDM operation may be executed under the condition that a specific one or plural input units among a remote controller input unit (not shown) and the input unit 46, such as a separate thermostat of the heat pump system 1, are designated, and the operations of the first indoor unit 30 and the second indoor unit 40 are limited to the heating or cooling operation according to heating/cooling mode change input through the designated input unit(s). Thereby, the compressor 14 may not be stopped/re-operated during the TDM alternating operation of the first indoor unit 30 and the second indoor unit 40, thus reducing an operation stopping time and facilitating improvement of life span and reliability of the compressor.

[0110] Through the above method, if it is judged that the simultaneous operating condition of the first indoor unit 30 and the second indoor unit 40 is satisfied, the heat pump system 1 in accordance with one embodiment of the present invention basically executes the TDM alternating operation. However, if one of other set conditions is satisfied, the heat pump system 1 preferentially executes the hot water operation or executes the simultaneous operation of the first indoor unit 30 and the second indoor unit 40, thereby being capable of driving multiple loads at the maximum output without any additional unit. Further, when the first indoor unit 30 and the second indoor unit 40 are simultaneously operated, sensory cooling or heating dissatisfaction generated due to a specific heat difference between air and water may be reduced.

[0111] As is apparent from the above description, in a heat pump system and a control method thereof in accordance with one embodiment, cooling and heating operations of an A2A indoor unit and cooling and heating operations and a hot water operation of an A2W indoor unit are effectively executed through a time division multiplexing (TDM) method without installation of any additional unit or increase of a capacity of an outdoor unit.

[0112] Further, a refrigerant distribution unit is installed and a preliminary heating operation is executed, thereby preventing shortage of a refrigerant during the heating operation when the indoor units are alternately operated through the TDM method.

[0113] Although a few embodiments have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.

Claims

1. A heat pump system comprising:

an outdoor unit including an outdoor air heat exchanger;
at least one first indoor unit including an indoor air heat exchanger;

- at least one second indoor unit including an indoor water-refrigerant heat exchanger;
 a refrigerant circulation pipe unit connected to the outdoor unit, the at least one first indoor unit, and the at least one second indoor unit to circulate a refrigerant; and
 a control unit controlling the at least one first indoor unit and the at least one second indoor unit so as to be alternately operated, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.
2. The heat pump system according to claim 1, further comprising:
- a water circulation pipe unit to circulate water having exchanged heat with the refrigerant in the at least one second indoor unit;
 a hot water tank connected to the water circulation pipe unit;
 a first sub heater to heat the water circulation pipe unit; and
 a second sub heater to heat the hot water tank, wherein the control unit executes a heating operation or a hot water operation of the at least one second indoor unit using at least one of the first sub heater and the second sub heater and controls the outdoor unit so as to execute a cooling operation of the at least one first indoor unit, if the heating operation or the hot water operation of the at least one second indoor unit is requested during the cooling operation of the at least one first indoor unit.
3. The heat pump system according to claim 1, further comprising an input unit, through which an operation mode of the at least one first indoor unit and the at least one second indoor unit is input, wherein the control unit controls the at least one first indoor unit and the at least one second indoor unit so as to be alternately operated under the condition that the operation of the at least one first indoor unit or the at least one second indoor unit is limited to a cooling mode or a heating mode according to the cooling mode or the heating mode input through the input unit.
4. The heat pump system according to claim 1, further comprising an input unit, through which an operation mode of the at least one first indoor unit and the at least one second indoor unit is input, wherein the control unit controls the at least one first indoor unit and the at least one second indoor unit so as to be operated in a hot water operation mode only, if the hot water operation mode is input through the input unit.
5. The heat pump system according to claim 1, wherein the control unit simultaneously operates the at least one first indoor unit and the at least one second indoor unit, upon judging that the sum total of a capacity required by the at least one first indoor unit and a capacity required by the at least one second indoor unit is less than a capacity of the outdoor unit.
6. The heat pump system according to claim 1, wherein the control unit preferentially operates any one of the at least one first indoor unit and the at least one second indoor unit, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.
7. The heat pump system according to claim 6, wherein the control unit preferentially operates the at least one first indoor unit, upon judging that the simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.
8. The heat pump system according to claim 7, wherein the control unit changes the operation of the at least one first indoor unit into the operation of the at least one second indoor unit, upon judging that the at least one first indoor unit reaches a first target temperature during the preferential operation of the at least one first indoor unit or the at least one first indoor unit is operated for a first set time.
9. The heat pump system according to claim 8, wherein the control unit stops the operation of the at least one second indoor unit, upon judging that the at least one second indoor unit reaches a second target temperature during the operation of the at least one second indoor unit or the at least one second indoor unit is operated for a second set time.
10. The heat pump system according to claim 9, wherein the control unit lowers the first target temperature by a reference value, if the first target temperature and the second target temperature are equal, the at least one second indoor unit is not operated, and the number of on/off of the operation of the at least one first indoor unit reaches a designated number.
11. A method of controlling a heat pump system having an outdoor unit including an outdoor air heat exchanger, at least one first indoor unit including an indoor air heat exchanger, at least one second indoor unit including an indoor water-refrigerant heat exchanger, and a water circulation pipe unit connected to the outdoor unit, the at least one first indoor unit, and the at least one second indoor unit to circulate a refrigerant, the method comprising:

alternately operating the at least one first indoor unit and the at least one second indoor unit, upon judging that a simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.

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12. The method according to claim 11, wherein any one of the at least one first indoor unit and the at least two indoor unit is preferentially operated, upon judging that the simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.

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13. The method according to claim 12, wherein the at least one first indoor unit is preferentially operated, upon judging that the simultaneous operating condition of the at least one first indoor unit and the at least one second indoor unit is satisfied.

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FIG. 1

1

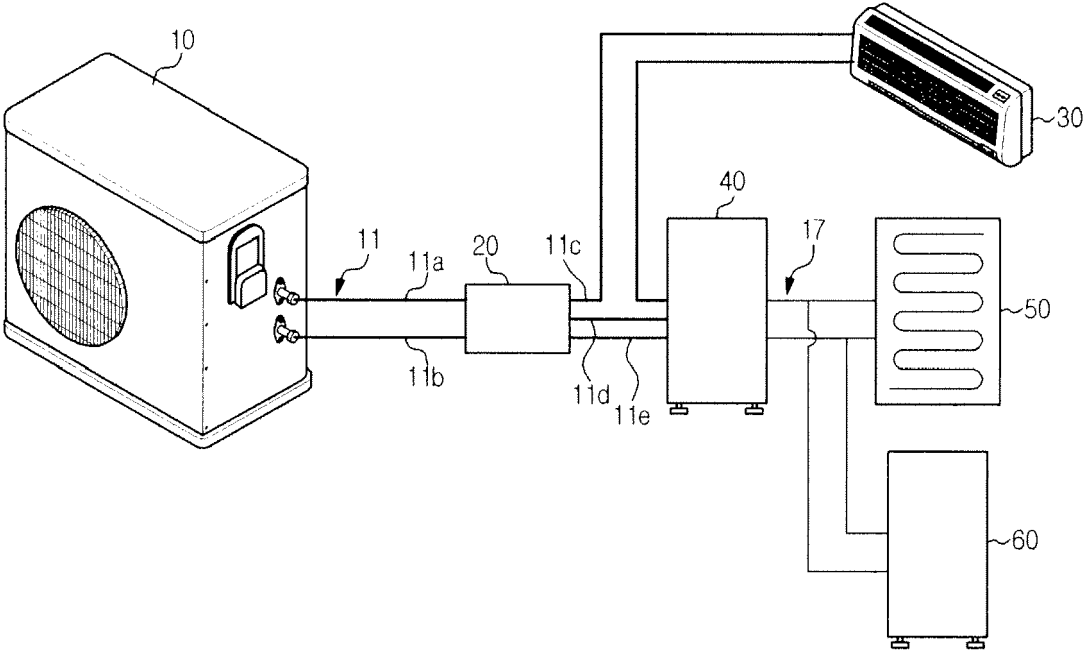


FIG. 2

2

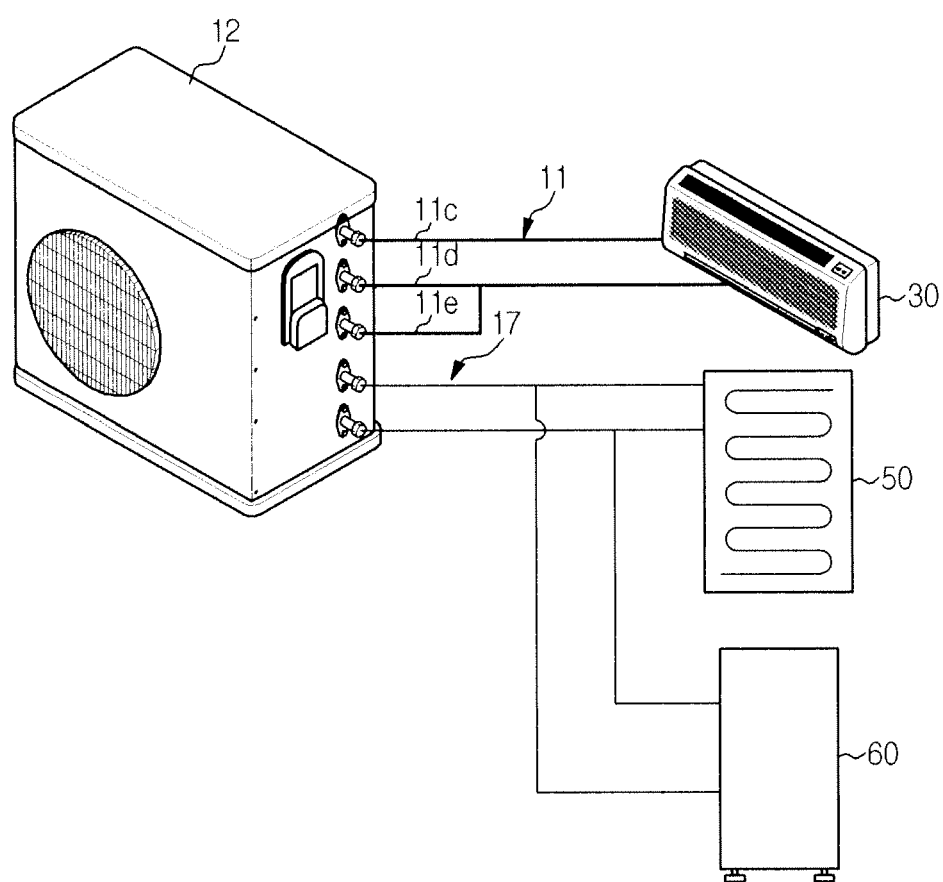


FIG. 3

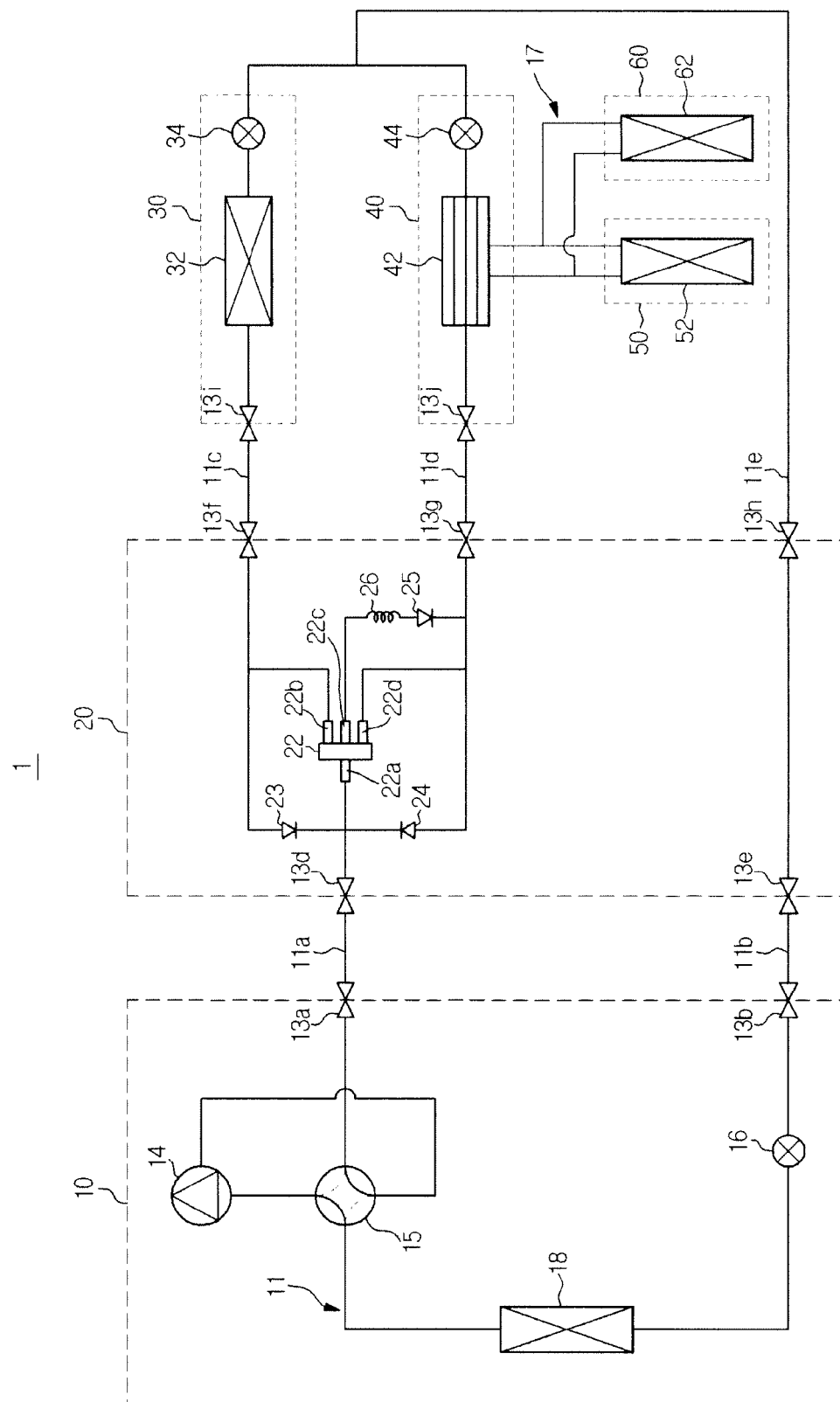


FIG. 4

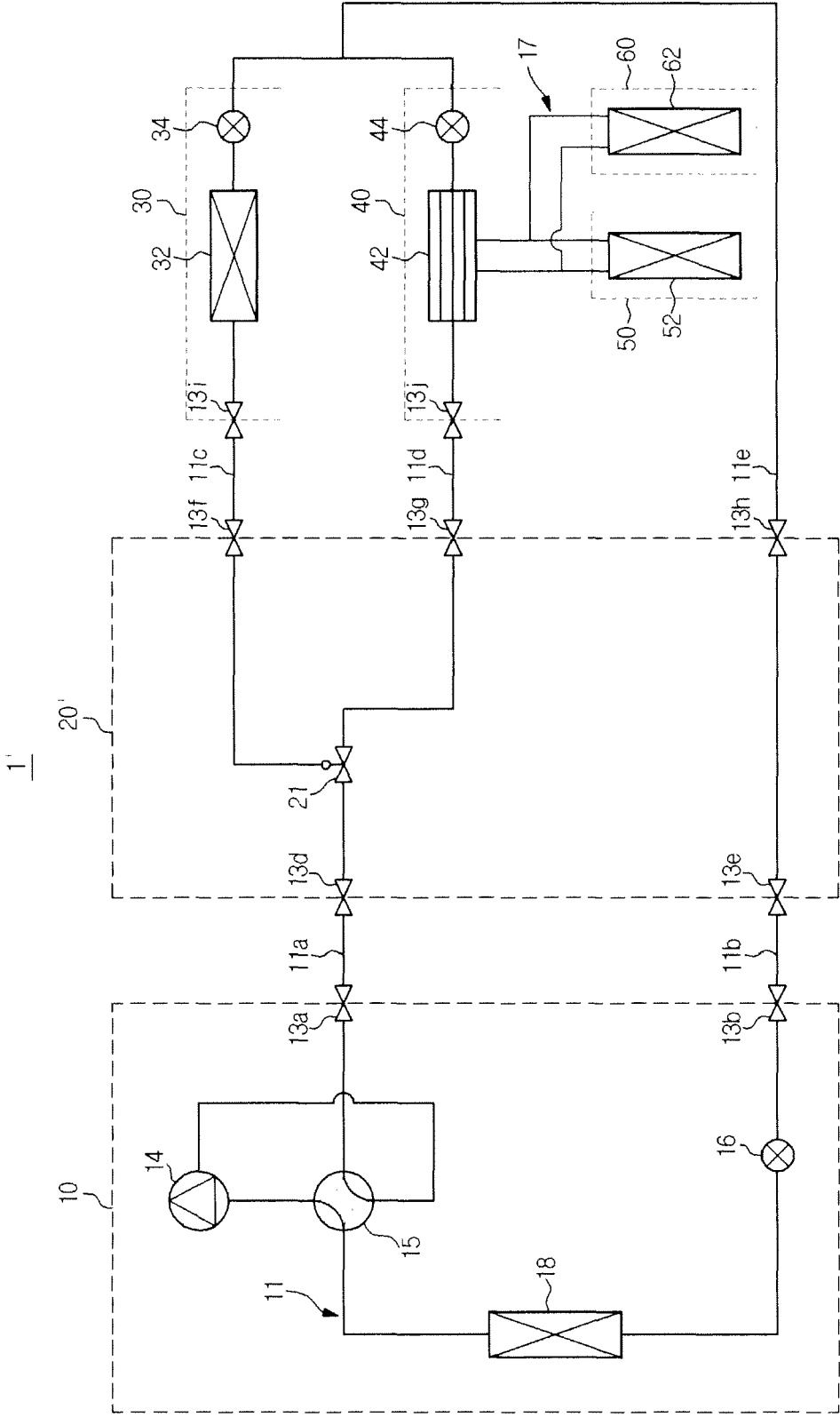


FIG. 5

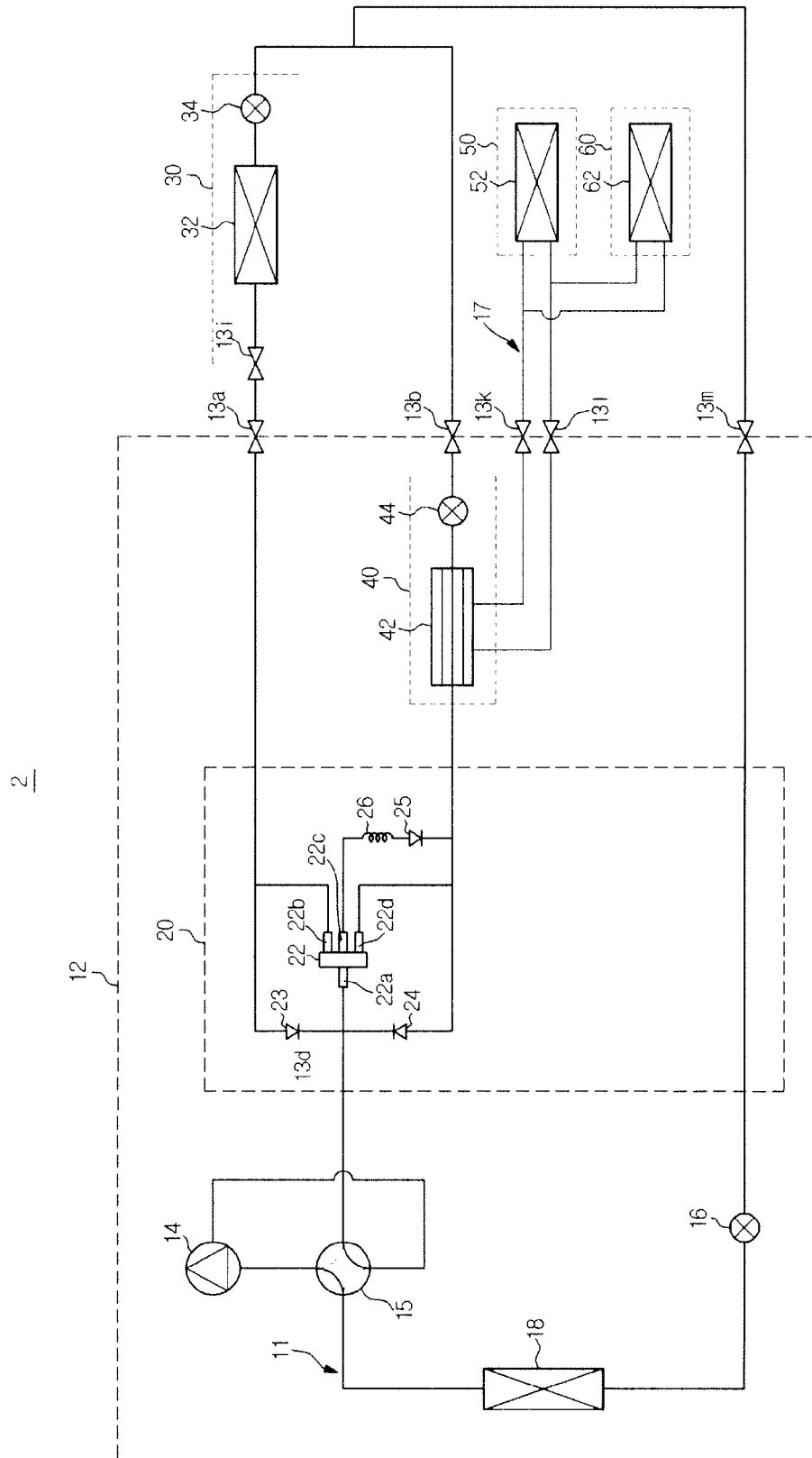


FIG. 6

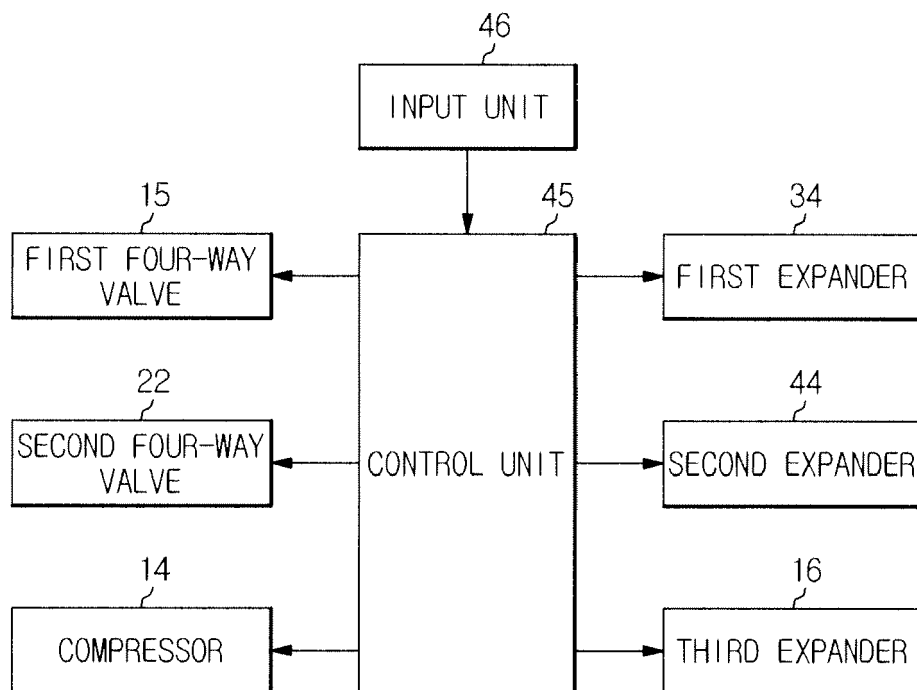


FIG. 7

1

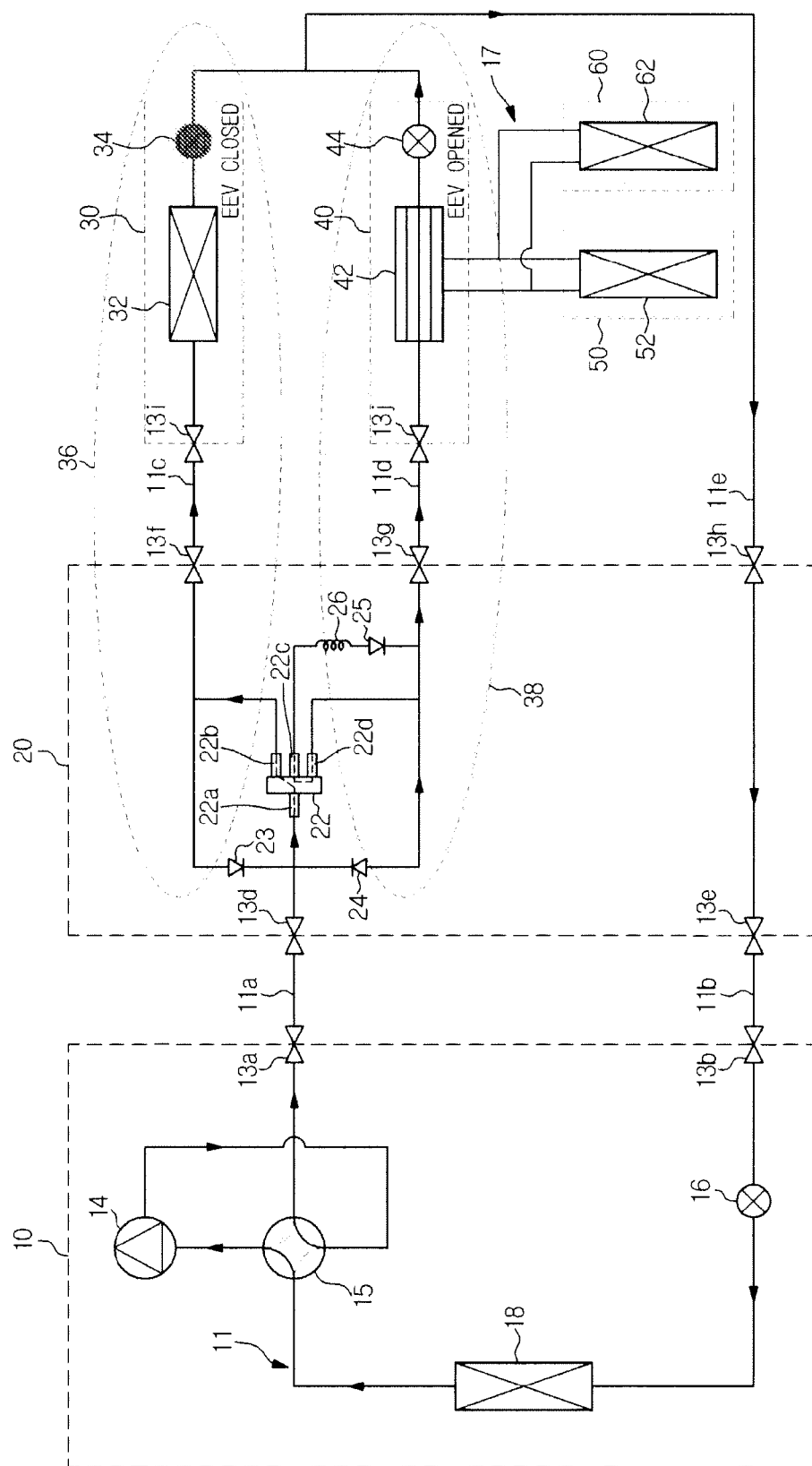


FIG. 8

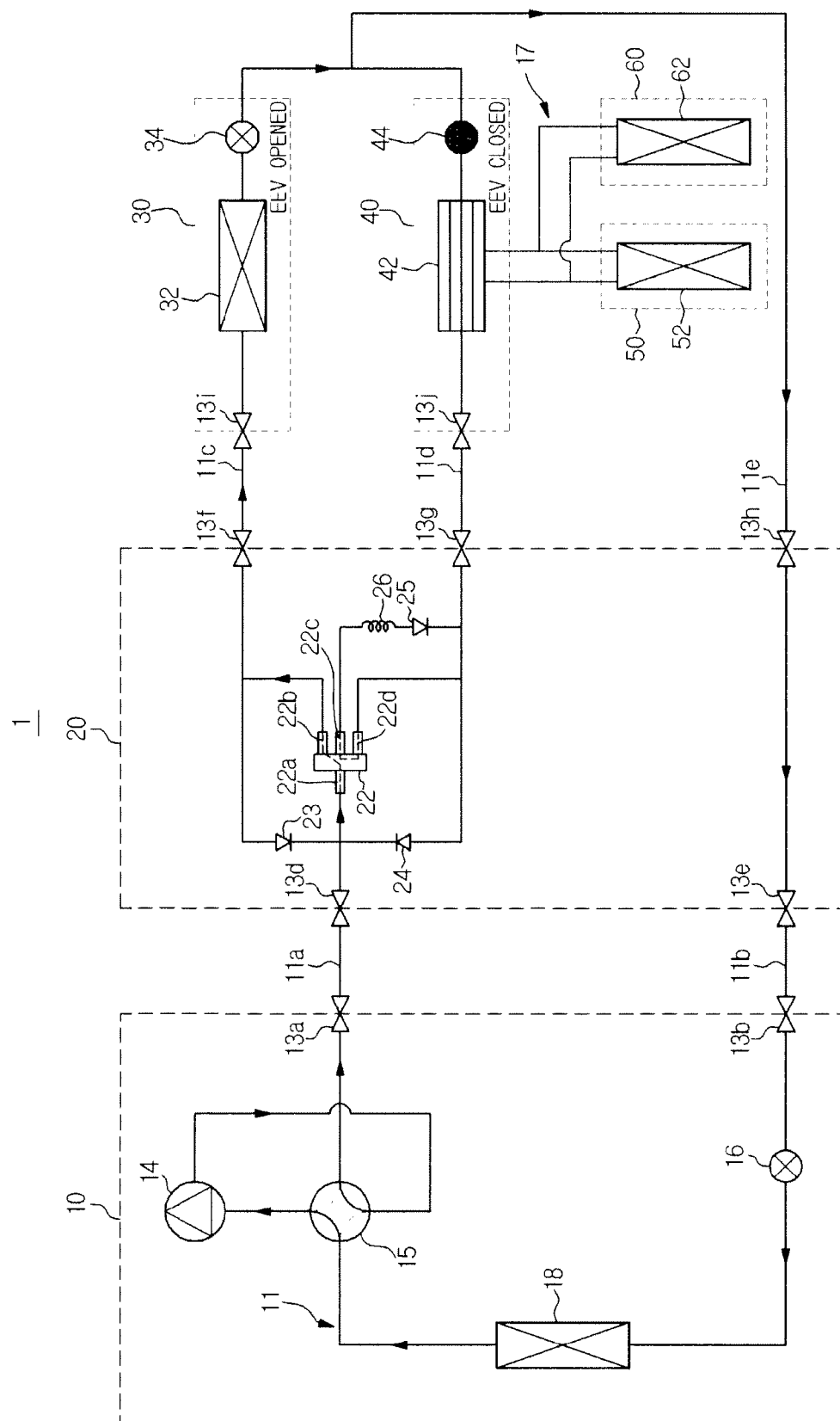


FIG. 9

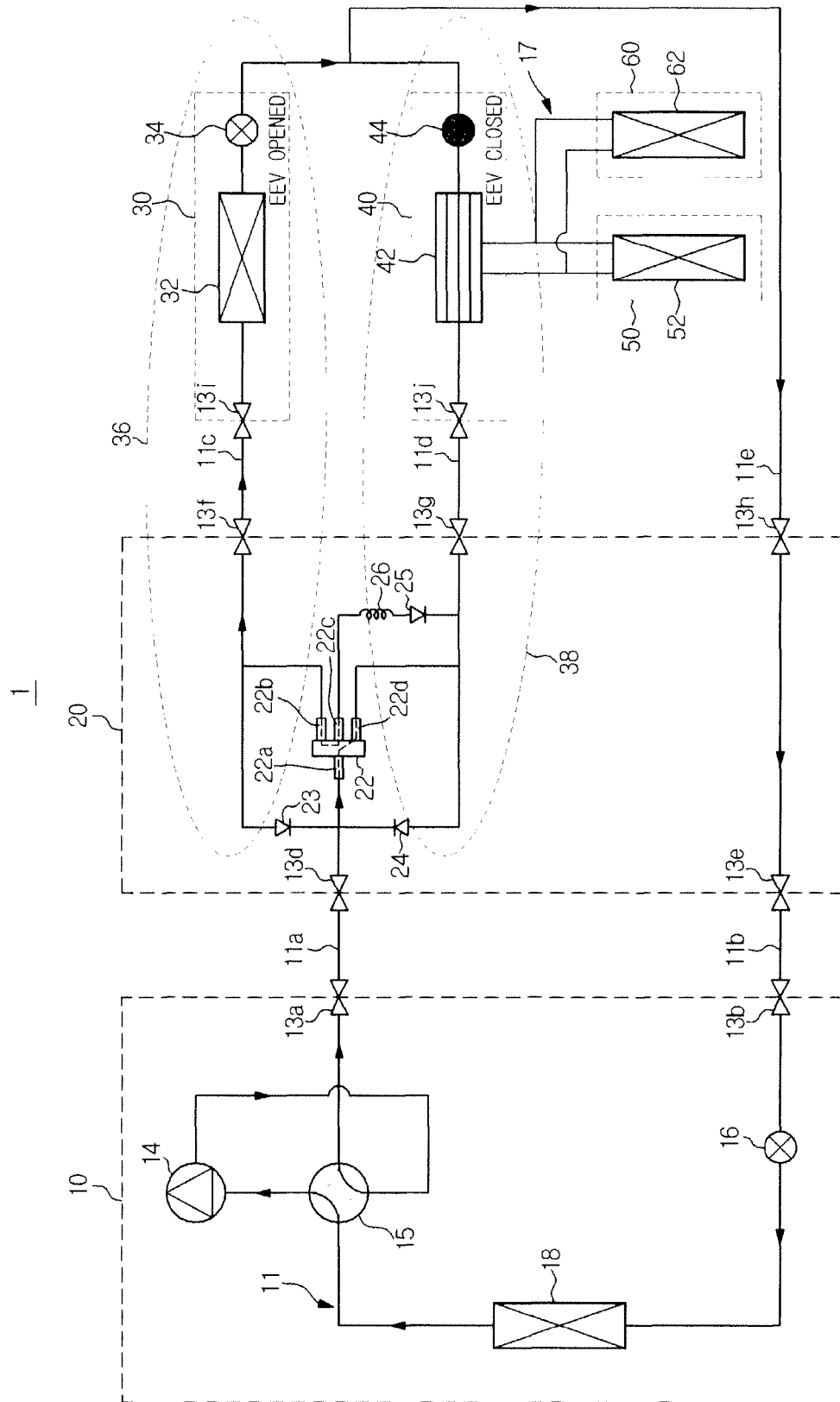


FIG. 10

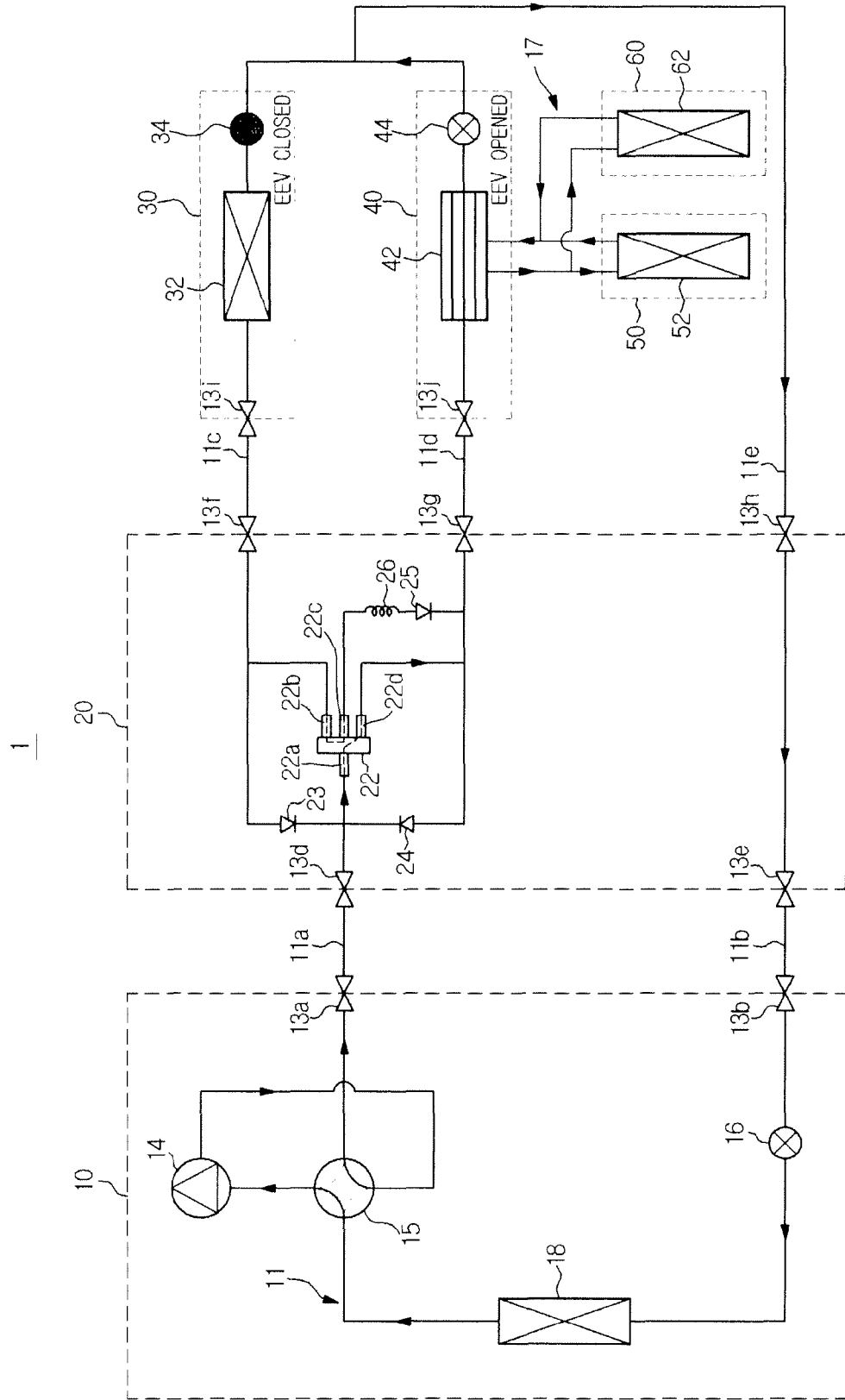


FIG. 11

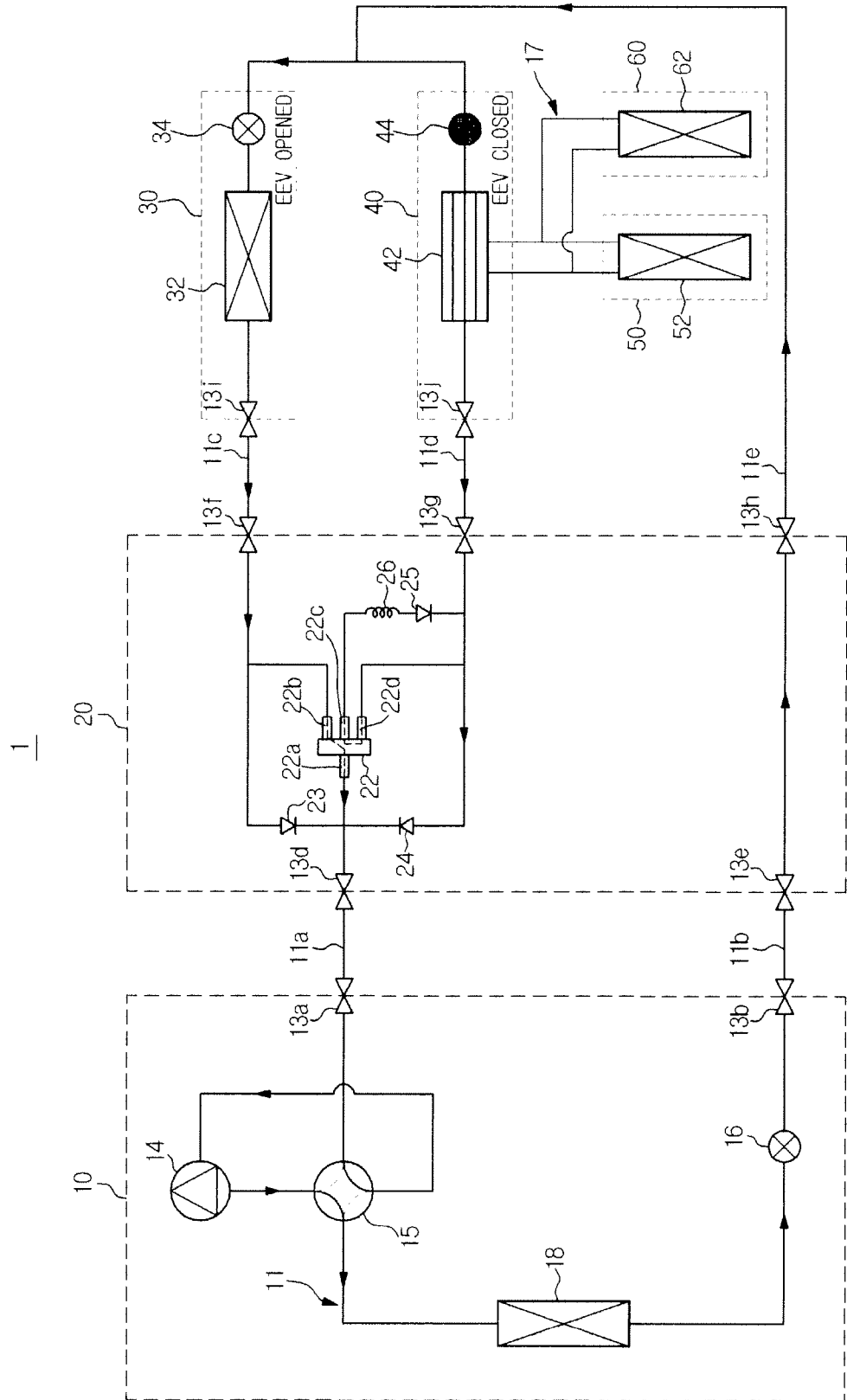


FIG. 12

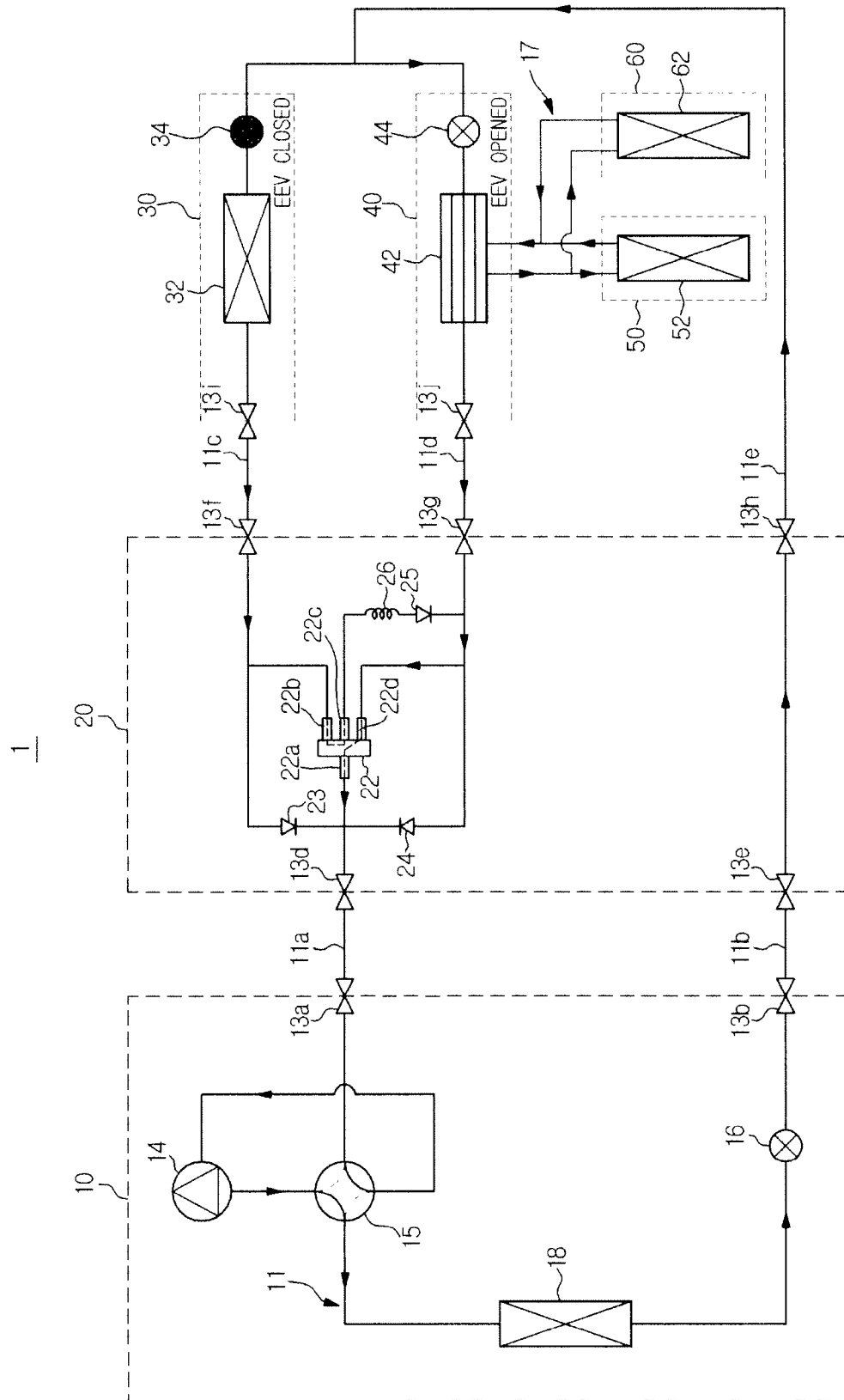


FIG. 13

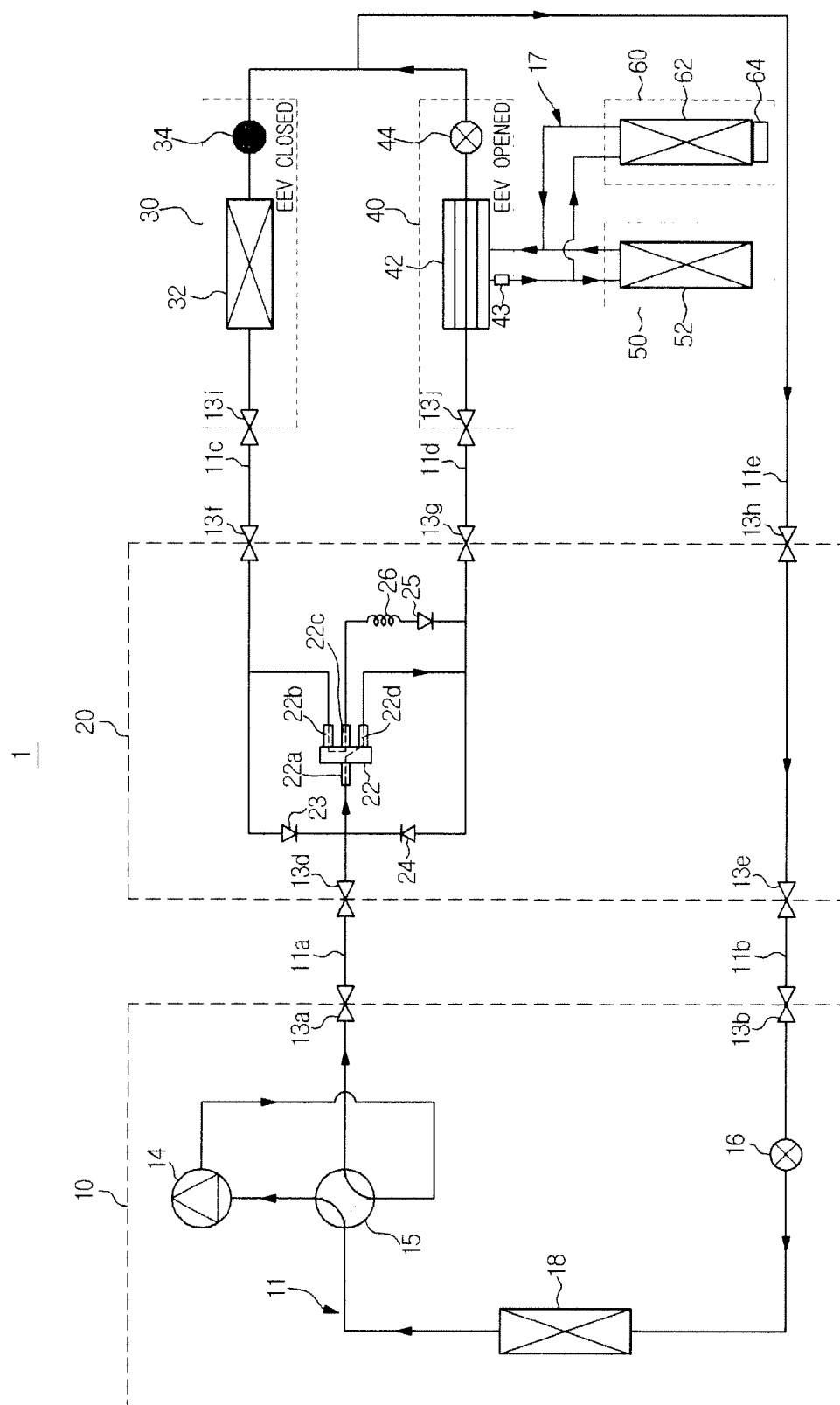


FIG. 14

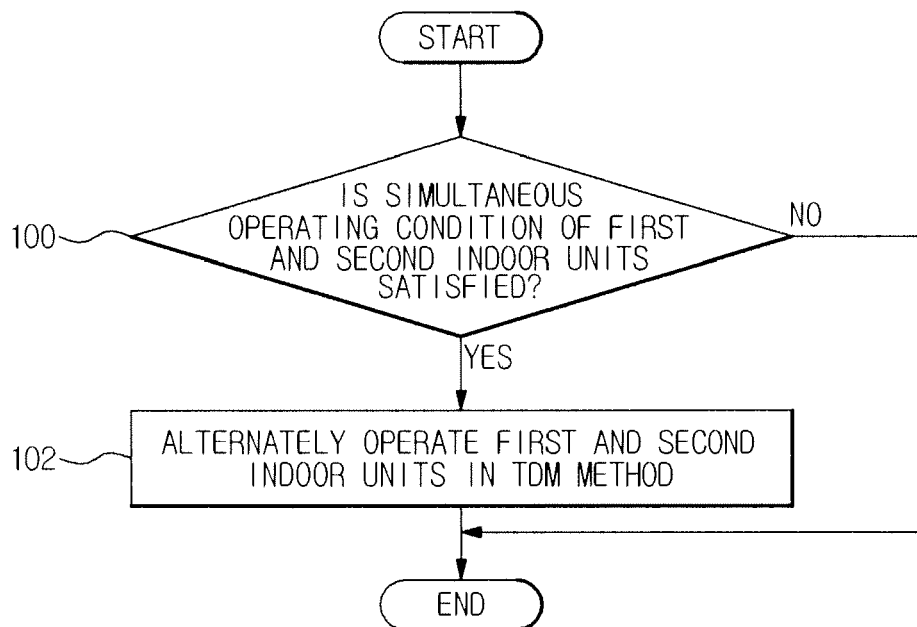


FIG. 15

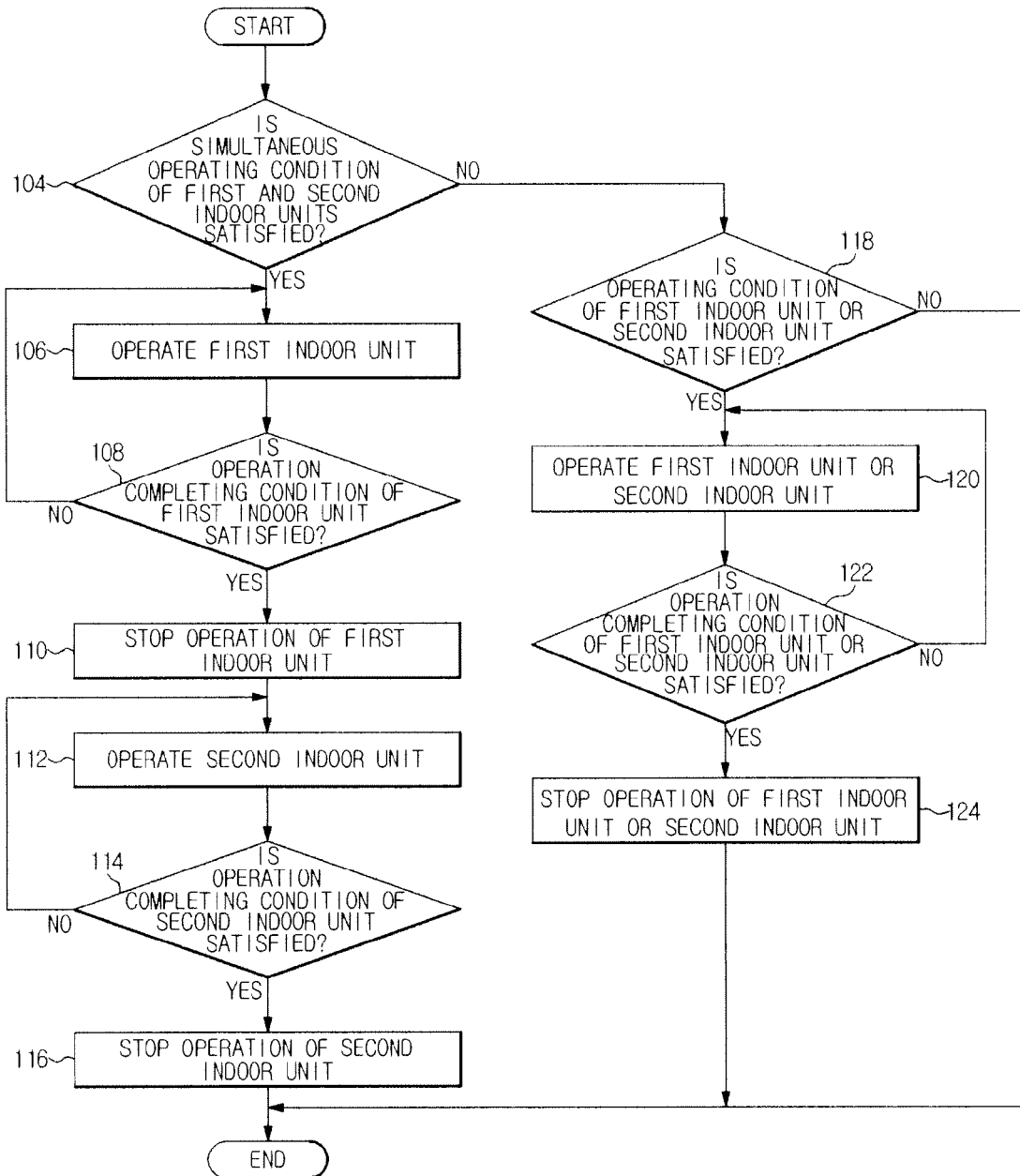


FIG. 16

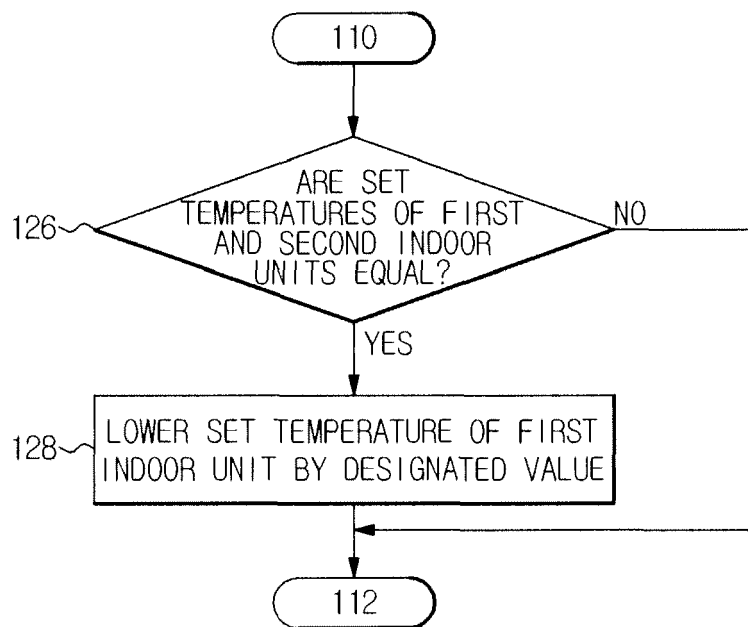


FIG. 17

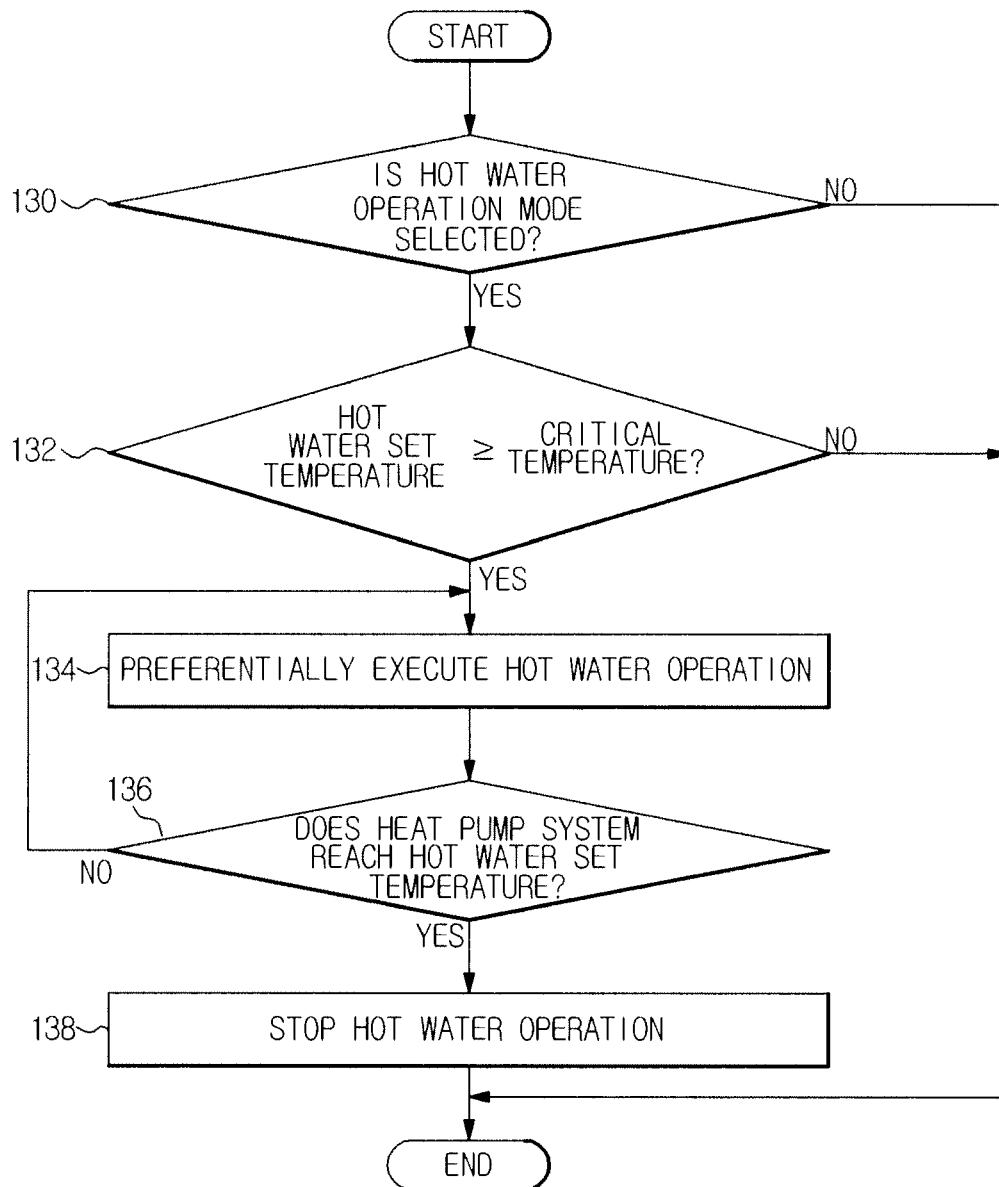


FIG. 18

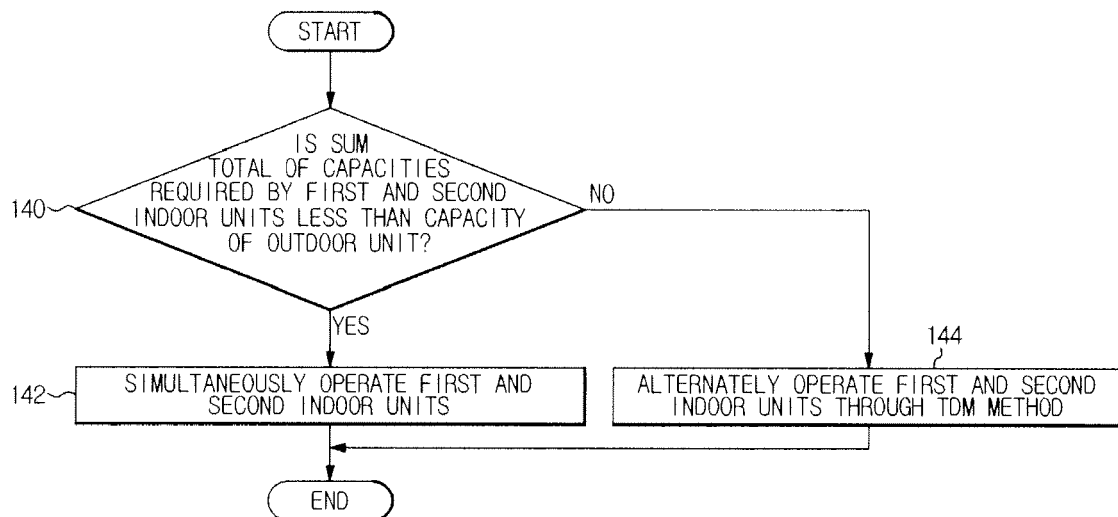


FIG. 19

