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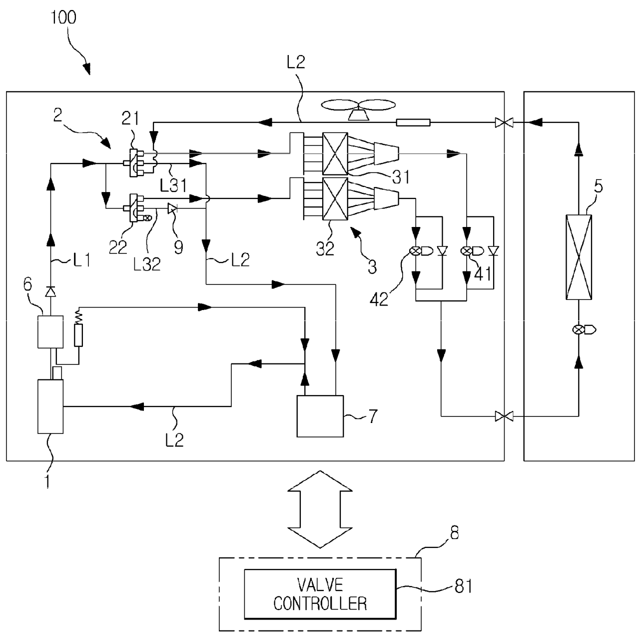
(54) **Air Conditioner**

(57) An air conditioner which controls capacity of an outdoor heat-exchanger unit without an on-off valve that exhibits high pressure loss, which prevents accumulation of refrigerant in an outdoor heat-exchanger, and which maintains reliability of a compressor or refrigeration cycle. The air conditioner includes a first expansion valve on a liquid line of a first outdoor heat-exchanger, a second expansion valve on a liquid line of a second outdoor heat-exchanger, a first connection line to connect a suction line to one port of the first 4-way valve, the suction line connecting a suction port of the compressor and an indoor heat-exchanger unit, a second connection line to connect the suction line to one port of the second 4-way valve, and a check valve provided on the second connection line to allow flow of refrigerant only from the second 4-way valve to the suction line.

FIG. 1



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Description

[0001] The present invention relates to an air conditioner, more particularly to an air conditioner which includes an outdoor heat-exchanger unit constructed by connecting a plurality of outdoor heat-exchangers in a row, capacity of the outdoor heat-exchanger unit being controllable during low-load operation.

[0002] For example, when an air conditioner is operated under low-load operating conditions, i.e. during heating operation under low indoor air-conditioning load and high outside temperature conditions or cooling operation under low indoor air-conditioning load and low outside temperature, evaporation or condensation capability of an outdoor heat-exchanger excessively increases, causing problematic operation. More specifically, if evaporation capability of the outdoor heat-exchanger excessively increases during heating operation under low-load operating conditions, discharge pressure of a compressor also excessively increases to exceed an upper limit thereof, which causes sudden shutdown of the compressor by a protective circuit. On the other hand, if condensation capability of the outdoor heat-exchanger excessively increases during cooling operation under low-load operating conditions, discharge pressure of the compressor decreases and has only a slight difference from suction pressure of the compressor, which causes an inappropriate compression ratio and makes it difficult to maintain reliability of the compressor.

[0003] Accordingly, there has been proposed an air conditioner in which a plurality of outdoor heat-exchangers is connected in a row to construct an outdoor heat-exchanger unit such that capacity of the outdoor heat-exchanger unit is controllable based on operating conditions.

[0004] For example, Japanese Patent Publication No. H59-180251 discloses an air conditioner in which electronic on-off valves are provided at front and rear sides of respective outdoor heat-exchangers constituting an outdoor heat-exchanger unit, and each electronic valve is switched off to lower capacity of the outdoor heat-exchanger unit under low-load operating conditions.

[0005] However, the conventional air conditioner constructed as described above may suffer from high pressure loss during flow of refrigerant due to the plurality of electronic on-off valves provided at front and rear sides of the respective outdoor heat-exchangers, thus deteriorating heating or cooling performance. However, using a large-scale electronic on-off valve to reduce pressure loss may not be beneficial in terms of cost. In addition, although it may be contemplated to reduce the number of electronic on-off valves, for example, by installing the electronic on-off valve only at the front or rear side of each outdoor heat-exchanger, this may cause accumulation of refrigerant in the outdoor heat-exchanger when the outdoor heat-exchanger is stopped, thus deteriorating the flow rate of refrigerant and cooling or heating performance.

[0006] It is an aspect of the present disclosure to provide an air conditioner which may control capacity of an outdoor heat-exchanger unit without using an on-off valve that exhibits high pressure loss, prevent accumulation of refrigerant in an outdoor heat-exchanger when the outdoor heat-exchanger is stopped, and maintain reliability of a compressor or refrigeration cycle.

[0007] Additional aspects of the disclosure 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 disclosure.

[0008] In accordance with one aspect of the disclosure, an air conditioner includes a refrigerant circuit constructed via annular connection of a compressor, a 4-way valve unit, an outdoor heat-exchanger unit, and an indoor heat-exchanger unit, wherein the outdoor heat-exchanger unit is divided into a first outdoor heat-exchanger and a second outdoor heat-exchanger, wherein the 4-way valve unit includes a first 4-way valve to switchably connect a gas line of the first outdoor heat-exchanger to any one of a discharge port or a suction port of the compressor, and a second 4-way valve to switchably connect a gas line of the second outdoor heat-exchanger to any one of the discharge port or the suction port of the compressor, and wherein the air conditioner includes a first expansion valve provided on a liquid line of the first outdoor heat-exchanger, a second expansion valve provided on a liquid line of the second outdoor heat-exchanger, a first connection line to connect a suction line and one port of the first 4-way valve to each other, the suction line connecting the suction port of the compressor and the indoor heat exchanger unit to each other, a second connection line to connect the suction line and one port of the second 4-way valve to each other, and a check valve provided on the second connection line to allow flow of refrigerant only from the second 4-way valve to the suction line.

[0009] Herein, the suction line may include a single suction line or a plurality of suction lines that connects the suction port of the compressor and the indoor heat-exchanger unit to each other. There may be examples in which the suction port of the compressor is connected to an accumulator via a single line and in turn the accumulator is connected to the indoor heat-exchanger unit via a single line such that the suction line consists of two lines, and in which an additional member is connected between the suction port of the compressor and the indoor heat-exchanger unit and the suction line consists of a plurality of lines.

[0010] With the above-described configuration, under low-load operating conditions, the second expansion valve is closed and the second 4-way valve is switched to connect the gas line of the second outdoor heat-exchanger to the suction port of the compressor so as to prevent refrigerant from flowing to the second outdoor heat-exchanger, which results in reduction in the capacity of the outdoor heat-exchanger unit. In this way, it may be possible to control capacity of the outdoor heat-exchanger unit without providing a refrigerant circuit with electronic on-off valves that exhibit high pressure loss, and to prevent deterioration in heating or cooling efficiency.

[0011] Although the electronic on-off valve is replaced by the two 4-way valves, no increase in cost occurs as compared to provision of a large-scale electronic valve because the 4-way valve is a member easy to restrict increase in cost even if the size thereof increases to prevent pressure loss.

[0012] As a result of providing the second connection line with the check valve to allow flow of refrigerant only from the second 4-way valve to the suction line, it may be possible to prevent the refrigerant from the suction line or the first connection line from accumulating in the second outdoor heat-exchanger through the second connection line even when the refrigerant is not directed to the second outdoor heat-exchanger, but directed to the first outdoor heat-exchanger. Accordingly, it may be possible to prevent abnormal increase in the discharge pressure of the compressor, or to prevent deterioration in the reliability of the compressor caused when a compression ratio is less than a predetermined value. Also, it may be possible to prevent deterioration in cooling performance due to accumulation of refrigerant in the second outdoor heat-exchanger when the second outdoor heat-exchanger is stopped.

[0013] As a detailed configuration to maintain a prescribed compression ratio by preventing excessive condensation capability of the outdoor heat-exchanger unit and reduction in the discharge pressure of the compressor during cooling operation in which indoor air-conditioning load is low and outside temperature is low, the air conditioner may further include a pressure meter to measure discharge pressure and suction pressure of the compressor, and a valve controller to control at least the second 4-way valve and the second expansion valve, and if a compression ratio that is a ratio of the discharge pressure to the suction pressure measured by the pressure meter is less than a predetermined compression ratio during cooling operation, the valve controller may switch the second 4-way valve such that the gas line of the second outdoor heat-exchanger is connected to the suction port of the compressor, and the valve controller may also close the second expansion valve.

[0014] To prevent a high-pressure protection circuit from stopping the compressor under conditions of excessive evaporation capability of the outdoor heat-exchanger unit and increased discharge pressure of the compressor during heating operation in which indoor air-conditioning load is low and outside temperature is high, the valve controller may close the second expansion valve if the discharge pressure measured by the pressure meter is greater than a predetermined value during heating operation. As a configuration to perform defrosting operation on each outdoor heat-exchanger, the 4-way valve unit may further include a main 4-way valve to switchably connect the indoor heat-exchanger unit to any one of the discharge port or the suction port of the compressor, the air conditioner may further include a first temperature sensor provided at the first outdoor heat-exchanger, a second temperature sensor provided at the second outdoor heat-exchanger, a bypass line to connect the liquid line of the outdoor heat-exchanger unit and the suction line of the compressor to each other, an auxiliary heat-exchanger provided on the bypass line to perform heat-exchange between refrigerant in the liquid line and refrigerant in the bypass line, and an auxiliary expansion valve provided on a liquid line of the auxiliary heat-exchanger of the bypass line, the valve controller may be configured to control the first 4-way valve, the main 4-way valve and the auxiliary expansion valve, and, if temperature detected by the first temperature sensor or the second temperature sensor is equal to or less than a predetermined value during heating operation in which the indoor heat-exchanger unit is connected to the discharge port of the compressor, the valve controller may switch the first 4-way valve or the second 4-way valve such that the gas line of the first outdoor heat-exchanger or the second outdoor heat-exchanger is connected to the discharge port of the compressor while maintaining the main 4-way valve to connect the indoor heat-exchanger unit and the discharge port of the compressor to each other, thereby allowing gas-phase refrigerant to be introduced into the first outdoor heat-exchanger or the second outdoor heat-exchanger, and the valve controller may also open the auxiliary expansion valve to allow liquid-phase refrigerant to be evaporated by the auxiliary heat-exchanger and gas-phase refrigerant to return to the suction line.

[0015] These and/or other aspects of the disclosure will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram illustrating an air conditioner during cooling operation according to an embodiment of the present disclosure;

FIG. 2 is a schematic diagram illustrating the case in which capacity of an outdoor heat-exchanger unit is reduced during cooling operation of the air conditioner according to the first-described embodiment of the present invention;

FIG. 3 is a graph illustrating variation of a compression ratio in the case in which capacity of the outdoor heat-exchanger unit is reduced during cooling operation of the air conditioner according to the first-described embodiment of the present disclosure;

FIG. 4 is a schematic diagram illustrating the air conditioner during heating operation according to the first-described embodiment of the present disclosure;

FIG. 5 is a schematic diagram illustrating the case in which capacity of the outdoor heat-exchanger unit is reduced during heating operation of the air conditioner according to the first-described embodiment of the present disclosure;

FIGS. 6A and 6B are graphs illustrating variation of pressure in the case in which capacity of the outdoor heat-exchanger unit is reduced during heating operation of the air conditioner according to the related art and the first-described embodiment of the present disclosure, respectively;

FIG. 7 is a schematic diagram illustrating an air conditioner during cooling operation according to another embodiment of the present disclosure;

FIG. 8 is a schematic diagram illustrating the case in which capacity of an outdoor heat-exchanger unit is reduced during cooling operation of the air conditioner with according to the secondly-described embodiment of the present disclosure;

FIG. 9 is a schematic diagram illustrating the air conditioner during heating operation according to the secondly-described embodiment of the present disclosure;

FIG. 10 is a schematic diagram illustrating the case in which capacity of the outdoor heat-exchanger unit is reduced during heating operation of the air conditioner according to the secondly-described embodiment of the present disclosure;

FIG. 11 is a diagram illustrating the concept of defrosting of the air conditioner according to the secondly-described embodiment of the present disclosure;

FIG. 12 is a schematic diagram illustrating a first defrosting operation of the air conditioner according to the secondly-described embodiment of the present disclosure;

FIG. 13 is a schematic diagram illustrating a second defrosting operation of the air conditioner according to the secondly-described embodiment of the present disclosure; and

FIG. 14 is a schematic diagram illustrating a third defrosting operation of the air conditioner according to the secondly-described embodiment of the present disclosure.

[0016] Reference will now be made in detail to the embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0017] The first-described embodiment of the present disclosure will now be described with reference to the drawings.

[0018] Referring to FIG. 1, an air conditioner, designated by reference numeral 100, according to the first-described embodiment includes a refrigerant circuit constructed by annular connection of a compressor 1, a 4-way valve unit 2, an outdoor heat-exchanger unit 3, and an indoor heat-exchanger unit 5. In the air conditioner 100, the 4-way valve unit 2 is used to connect a connection for a discharge port or a suction port of the compressor 1 to any one of the outdoor heat-exchanger unit 3 or the indoor heat-exchanger unit 5, such that each heat-exchanger unit functions as a condenser or an evaporator to enable selective switching of room cooling and room heating. In the air conditioner 100 according to the first-described embodiment, to change heat-exchange capabilities of the outdoor heat-exchanger unit 3 based on outside temperature or indoor load, the 4-way valve unit 2 includes a first 4-way valve 21 and a second 4-way valve 22, and similarly the outdoor heat-exchanger unit 3 is divided into a first outdoor heat-exchanger 31 and a second outdoor heat-exchanger 32. Additionally, an oil separator 6 is provided at the discharge side of the compressor 1 to return oil collected by an oil collecting line to the suction side of the compressor 1. An accumulator 7 is located on a suction line L2 to allow only gas-phase refrigerant separated from liquid-phase refrigerant to be suctioned into the compressor 1. Additionally, the air conditioner 100 includes a control device 8 to control a variety of elements, such as the 4-way valve unit 2 or expansion valves, and the like, that will be described hereinafter.

[0019] A connection configuration of the 4-way valve unit 2 and the outdoor heat-exchanger unit 3 will be described below based on cooling operation under typical operating conditions illustrated in FIG. 1. Flow of refrigerant through each line will be represented by arrows on lines, and a closed state of the expansion valve will be represented by a black circle.

[0020] The refrigerant discharged from the discharge port of the compressor 1 passes through the oil separator 6, and then is directed to two branch paths, i.e. a first branch path and a second branch path. After passing through the 4-way valve, outdoor heat-exchanger and expansion valve provided on each branch path, the refrigerant is merged and passes through the indoor heat-exchanger unit 5. The refrigerant having passed through the indoor heat-exchanger unit 5 reaches the suction line L2 connected to the suction port of the compressor 1 by way of the first 4-way valve 21, and is returned to the compressor 1.

[0021] More specifically, the first 4-way valve 21, first outdoor heat-exchanger 31, and first expansion valve 41 on a liquid line of the first outdoor heat-exchanger 31 are sequentially arranged in parallel on the first branch path.

[0022] The first 4-way valve 21 switchably connects a gas line of the first outdoor heat-exchanger 31 to any one of the discharge port or the suction port of the compressor 1. More specifically, a first port of the first 4-way valve 21 is connected to a discharge line L1 connected to the discharge port of the compressor 1. The first 4-way valve 21 has a second port connected to the gas line of the first outdoor heat-exchanger 31, a third port connected to a first connection line L31 connected to the suction line L2 that is in turn connected to the suction port of the compressor 1, and a fourth port connected to a liquid line of the indoor heat-exchanger unit 5.

[0023] In the case in which the first outdoor heat-exchanger 31 functions as a condenser and the first branch path functions as a cooling circuit, no voltage is applied to the first 4-way valve 21 to switch off the first 4-way valve 21 such that the first port and the second port communicate with each other and the third port and the fourth port communicate with each other. On the other hand, in the case in which the first outdoor heat-exchanger 31 functions as an evaporator and the first branch path functions as a heating circuit, voltage is applied to the first 4-way valve 21 to switch on the first 4-way valve 21 such that the first port and the fourth port communicate with each other and the second port and the third port communicate with each other.

[0024] The second 4-way valve 22, second outdoor heat-exchanger 32, and second expansion valve 42 on a liquid line of the second outdoor heat-exchanger 32 are sequentially arranged in parallel on the second branch path, similar to those as on the first branch path.

[0025] The second 4-way valve 22 switchably connects a gas line of the second outdoor heat-exchanger 32 to any one of the discharge port or the suction port of the compressor 1, but this connection partially differs from that as in the first 4-way valve 21. More specifically, a first port of the second 4-way valve 22 is connected to the discharge line L1 connected to the discharge port of the compressor 1. The second 4-way valve 22 has a second port connected to the gas line of the second outdoor heat-exchanger 32, and a third port connected to a second connection line L32 connected to the suction line L2. Unlike the first 4-way valve 21, a check valve 9 is provided on the second connection line L32 to allow flow of the refrigerant only from the second 4-way valve 22 to the suction line L2, and a fourth port of the second 4-way valve 22 is closed. Providing the check valve 9 on the second connection line L32 prevents the refrigerant in the suction line L2 from flowing backward to the second outdoor heat-exchanger 32 through the second 4-way valve 22 and from accumulating in the second outdoor heat-exchanger 32 when the second circuit serves as a heating circuit.

[0026] In the case in which the second outdoor heat-exchanger 32 functions as a condenser and the second branch path functions as a cooling circuit, no voltage is applied to the second 4-way valve 22 to switch off the second 4-way valve 22 such that only the first port and the second port communicate with each other. Although the third port and the fourth port are connected to each other while the first port and the second port communicate with each other, the fourth port is closed, and therefore no flow of refrigerant occurs between the third port and the fourth port. On the other hand, in the case in which the second outdoor heat-exchanger 32 functions as an evaporator and the second branch path functions as a heating circuit, voltage is applied to the second 4-way valve 22 to switch on the second 4-way valve 22 such that only the second port and the third port communicate with each other.

[0027] The control device 8 is a computer having a Control Processing Unit (CPU), memory, I/O channel, input/output device, AD/DA converter, or the like. As the CPU or the peripheral device is operated based on a program stored in the memory, each component of the air conditioner 100 is controlled.

[0028] The control device 8 of the first-described embodiment at least functions as a valve controller 81. The valve controller 81 controls at least the second 4-way valve 22 and the second expansion valve 42 based on a measured value of a pressure meter (not shown) that measures discharge pressure and suction pressure of the compressor 1, to prevent deterioration in the reliability of the compressor 1 caused when the compressor 1 fails to maintain a prescribed compression ratio. Hereinafter, a configuration of the valve controller 81 as well as operation of the air conditioner 100 will be described. First, operation of the valve controller 81 will be described in relation to the case in which the air conditioner 100 performs cooling operation under lower-load conditions of low outside temperature and low indoor load. Cooling operation of the air conditioner 100 according to the first-described embodiment, as illustrated in FIG. 1, refers to operation in which the first 4-way valve 21 and the second 4-way valve 22 are in an off-state and both the first outdoor heat-exchanger 31 and the second outdoor heat-exchanger 32 serve as a condenser.

[0029] Continuing cooling operation under low-load conditions may decrease discharge pressure of the compressor 1, causing a small difference between the discharge pressure and suction pressure of the compressor 1. This makes it difficult for the compressor 1 to operate at a recommended compression ratio and causes breakdown of the compressor, for example. If the compression ratio that is a ratio of discharge pressure to suction pressure measured by the pressure meter is less than a predetermined compression ratio during cooling operation, as illustrated in FIG. 2, the valve controller 81 switches the second 4-way valve 22 such that the gas line of the second outdoor heat-exchanger 32 is connected to the suction port of the compressor 1, and the valve controller 81 also closes the second expansion valve 42.

[0030] That is, if reduction in the compression ratio is detected, the valve controller 81 switches on the second 4-way valve 22 such that the first port is connected to the fourth port and is closed while the second port and the third port communicate with each other. Since the second expansion valve 42 is closed by the valve controller 81, the second branch path on which the second outdoor heat-exchanger 32 is provided is separated from the circuit, and no flow of the refrigerant occurs. As such, the refrigerant flows only through the first outdoor heat-exchanger 31, which allows capacity of the outdoor heat-exchanger unit 3 to be reduced based on low-load conditions. Once capacity of the outdoor heat-exchanger unit 3 is reduced to conform to low-load conditions, discharge pressure of the compressor 1 increases as illustrated in the graph of FIG. 3, which allows the compressor 1 to return from the low compression ratio to a normal compression ratio. In this way, the compressor 1 may remain reliable.

[0031] Moreover, the check valve 9 provided on the second connection line L32 may prevent the refrigerant, which returns from the indoor heat-exchanger unit 5 to the suction port 1 of the compressor 1 by way of the fourth and third ports of the first 4-way valve 21, from flowing backward to the second outdoor heat-exchanger 32. That is, when capacity of the outdoor heat-exchanger unit 3 is reduced based on low-load conditions, it may be possible to prevent the refrigerant from accumulating in the second outdoor heat-exchanger 32 when the second outdoor heat-exchanger 32 is stopped, and to prevent deterioration in cooling capability due to a lower flow rate of refrigerant. Next, operation of the valve controller 81 will be described in relation to the case in which the air conditioner 100 performs heating operation under low load conditions of high outside temperature and low indoor load. Also, to operate each outdoor heat-exchanger as an evaporator during heating operation of a typical output, each 4-way valve, as illustrated in FIG. 4, is switched such that the first port and the fourth port are connected to each other and the second port and the third port communicate with each other, to ensure connection between the gas line of each outdoor heat-exchanger and the suction port of the compressor 1.

[0032] Continuing heating operation under low load conditions, as illustrated in the graph of FIG. 6A, discharge pressure of the compressor 1 continuously increases. Thus, for safety, operation of the compressor 1 may stop by high-pressure protection. To prevent unwanted shutdown of the compressor 1, the valve controller 81, as illustrated in FIG. 5, closes the second expansion valve 42 if discharge pressure measured by the pressure meter exceeds a predetermined value during heating operation. That is, the refrigerant having passed through the indoor heat-exchanger unit 5 passes through only the first heat-exchanger 31 because the second expansion valve 42 is closed, which may reduce capacity of the outdoor heat-exchanger unit 3. If capacity of the outdoor heat-exchanger unit 3 is reduced, as illustrated in FIG. 6B, discharge pressure of the compressor 1 decreases, which may prevent execution of a high-pressure protective circuit. Unlike the above-described cooling operation, the second 4-way valve 22 remains in an original on-state during heating operation, and thus particular change does not occur. Even in this case, owing to the check valve 9 provided on the second connection line L32, it may be possible to prevent the refrigerant, which returns from the first outdoor heat-exchanger 31 to the suction port of the compressor 1 through the suction line L2, from flowing backward from the second connection line L32 and from accumulating in the second outdoor heat-exchanger 32.

[0033] The air conditioner 100 according to the first-described embodiment has the effect of reducing capacity of the outdoor heat-exchanger unit 3 based on low-load conditions of cooling operation or low load conditions of heating operation by switching on or off the second 4-way valve 22 and closing the second expansion valve 42. That is, it may be unnecessary to provide electronic on-off valves, which have conventionally been employed to prevent flow of refrigerant through the second outdoor heat-exchanger 32, at front and rear sides of the second outdoor heat-exchanger 32.

[0034] Further, owing to providing the check valve 9 on the second connection line L32 connected to the suction line L2, it may be possible to prevent the refrigerant from accumulating in the second outdoor heat-exchanger 32, similar to using electronic on-off valves.

[0035] Accordingly, since electronic on-off valves that cause high pressure loss may be unnecessary to realize variable capacity of the outdoor heat-exchanger unit 3, and also since 4-way valves that exhibit low pressure loss and are low cost despite a large size thereof may be used, it may be possible to prevent significant increase in manufacturing costs without deterioration in the performance of a refrigeration circuit.

[0036] The air conditioner 100 according to the secondly-described embodiment of the present disclosure will now be described. Elements corresponding to those of the air conditioner 100 of the first-described embodiment will be designated by the same reference numerals.

[0037] The air conditioner 100 of the secondly-described embodiment includes not only a configuration for variable capacity of the outdoor heat-exchanger unit 3 via switching of flow of refrigerant to any one of a plurality of outdoor heat-exchangers, but also a configuration for defrosting of each outdoor heat-exchanger.

[0038] More specifically, the air conditioner 100 of the secondly-described embodiment, as illustrated in FIG. 7, differs from the air conditioner 100 of the first-described embodiment with respect to a configuration of the 4-way valve unit 2. Additionally, the air conditioner 100 of the secondly-described embodiment further includes an auxiliary heat-exchanger 33 provided on a bypass line L4 that connects the liquid line of the outdoor heat-exchanger unit 3 and the suction line L2 of the compressor 1 to each other, and an auxiliary expansion valve 43 provided on a liquid line of the auxiliary heat-exchanger 33 of the bypass line L4. Also, for defrosting, the valve controller 81 is changed in configuration to further control the first 4-way valve 21, a main 4-way valve 23 that will be described hereinafter, and the auxiliary expansion valve 43.

[0039] Different elements from those of the first-described embodiment will be described below in more detail.

[0040] The 4-way valve unit 2 includes the first 4-way valve 21, the second 4-way valve 22, and the main 4-way valve 23 provided between the 4-way valves 21 and 22 and the discharge port of the compressor 1. The main 4-way valve 23 switchably connects the gas line of the indoor heat-exchanger unit 5 to any one of the discharge port or the suction port of the compressor 1. More specifically, a first port of the main 4-way valve 23 is connected to the discharge line L1 connected to the discharge port of the compressor 1. The main 4-way valve 23 has a second port connected to the gas line of the indoor heat-exchanger unit 5, and a third port connected to the suction line L2 that is in turn connected to the suction port of the compressor 1. A fourth port of the main 4-way valve 23 is closed. In a first state of the main 4-way valve 23, the first port and the second port communicate with each other and the third port and the fourth port communicate with each other. Also, in a second state of the main 4-way valve 23, the first port and the fourth port communicate with each other and the second port and the third port communicate with each other. The main 4-way valve 23 is switched such that the first port and the fourth port communicate with each other during cooling operation and the first port and the second port communicate with each other during heating operation.

[0041] Addition of the main 4-way valve 23 causes change in a connection configuration of the first 4-way valve 21. The fourth port of the first 4-way valve 21 is connected to the indoor heat-exchanger unit 5 in the first-described embodiment, but is closed in the secondly-described embodiment. Also, to connect the first port of the first 4-way valve 21 and the discharge port of the compressor 1 to each other, the discharge line L1 is branched so as to be connected to the first port of the main 4-way valve 23 and the first port of the first 4-way valve 21.

[0042] Even in the air conditioner 100 of the secondly-described embodiment having the above-described configuration, capacity of the outdoor heat-exchanger unit 3 may be appropriately changed even without providing electronic on-off valves on the refrigerant circuit similar to the first-described embodiment.

[0043] More specifically, if discharge pressure of the compressor 1 decreases under low-load conditions during cooling operation as illustrated in FIG. 7, the second 4-way valve 22 is switched to suit to a heating mode and is closed while the main 4-way valve 23 remains in a cooling mode to enable introduction of refrigerant from the indoor heat-exchanger unit 5 as illustrated in FIG. 8.

[0044] Also, if discharge pressure of the compressor 1 excessively increases under low load conditions during heating operation as illustrated in FIG. 9, the second expansion valve 42 is closed while the main 4-way valve 23, the first 4-way valve 21 and the second 4-way valve 22 remain in a heating mode as illustrated in FIG. 10.

[0045] As such, similar to the first-described embodiment, it may be possible to reduce capacity of the outdoor heat-exchanger unit as necessary, and to maintain a predetermined compression ratio or reduce discharge pressure of the compressor 1. Moreover, as a result of providing the check valve 9 on the second connection line L32, it may be possible to prevent the refrigerant from flowing backward from the suction line L2 and from accumulating in the second outdoor heat-exchanger 32.

[0046] Next, defrosting of the air conditioner 100 during heating operation according to the secondly-described embodiment will be described.

[0047] During defrosting, as illustrated in FIG. 11, only the first outdoor heat-exchanger 31 is first subjected to defrosting, and then the first outdoor heat-exchanger 31 and the second outdoor heat-exchanger 32 are simultaneously subjected to defrosting, and thereafter only the second outdoor heat-exchanger 32 is subjected to defrosting. Here, the valve controller 81 opens the auxiliary expansion valve 43 during simultaneous defrosting of the first outdoor heat-exchanger 31 and the second outdoor heat-exchanger 32 to cause evaporation of liquid-phase refrigerant by the auxiliary heat-exchanger 33 and allow gas-phase refrigerant to return to the suction line L2. More specifically, if temperature detected by a first temperature sensor (not shown) or a second temperature sensor (not shown) is equal to or less than a predetermined value during heating operation, the valve controller 81, as illustrated in FIG. 12, first maintains the main 4-way valve 23 in a heating mode, switches the first 4-way valve 21 to suit to a cooling mode and maintains the second 4-way valve 22 in a heating mode, thereby allowing gas-phase refrigerant to be introduced into the first outdoor heat-exchanger 31. In this way, defrosting of the first outdoor heat-exchanger 31 is achieved as high-temperature gas-phase refrigerant is introduced into the first outdoor heat-exchanger 31. The defrosting of the first outdoor heat-exchanger 31 ends when temperature detected by the first temperature sensor becomes a predetermined value or more (e.g., 1ºC or more). The auxiliary expansion valve 43 is closed during defrosting of only the first outdoor heat-exchanger 31.

[0048] The valve controller 81 functions to delay detection of the first temperature sensor such that the detected temperature is acquired after predetermined time has passed from beginning of defrosting of the first outdoor heat-exchanger 31. Since the high-temperature gas-phase refrigerant is introduced at once into the first outdoor heat-exchanger 31 immediately after the first 4-way valve 21 is switched to begin defrosting, temperature detected by the first temperature sensor may temporally show a sudden increase. Delaying detection of the first temperature sensor for a predetermined time (e.g., 60 seconds) may prevent detection of an abnormally increased initial temperature.

[0049] Next, the valve controller 81, as illustrated in FIG. 13, simultaneously switches the first 4-way valve 21 and the second 4-way valve 22 to suit to a cooling mode such that high-temperature gas-phase refrigerant is introduced into the first outdoor heat-exchanger 31 and the second outdoor heat-exchanger 32 for a predetermined time T (e.g., 30 seconds), and the valve controller 81 also opens the auxiliary expansion valve 43 for a predetermined time T (e.g., 30 seconds) such that liquid-phase refrigerant is evaporated by the auxiliary heat-exchanger 33 to allow gas-phase refrigerant to return to the suction line L2.

[0050] Next, the valve controller 81, as illustrated in FIG. 14, switches the first 4-way valve 22 to suit to a heating mode, and maintains the second 4-way valve 22 in a cooling mode, thereby allowing the gas-phase refrigerant to be introduced into the second outdoor heat-exchanger 32. Thereby, defrosting of the second outdoor heat-exchanger 32 is achieved as high-temperature gas-phase refrigerant is introduced into the second outdoor heat-exchanger 32. The defrosting of the second outdoor heat-exchanger 32 ends when temperature detected by the second temperature sensor becomes a predetermined value or more (e.g., 1ºC or more), and the second 4-way valve 22 is switched to suit to a heating mode to enable implementation of typical heating operation. The auxiliary expansion valve 43 is closed during defrosting of only the second outdoor heat-exchanger 32.

[0051] The air conditioner 100 according to the secondly-described embodiment having the above-described configuration may continuously implement heating operation even during defrosting by enabling alternate defrosting of the first outdoor heat-exchanger 31 and the second outdoor heat-exchanger 32 while maintaining reliability of the compressor 1, which may restrict reduction of a room temperature during defrosting, and consequently create pleasant indoor environment.

[0052] Other embodiments may also be possible.

[0053] The refrigerant lines and connection methods of the respective 4-way valves according to the respective embodiments are given by way of example, and any other connection methods may be possible so long as they enable switching of cooling and heating operations and prevent flow of refrigerant to a selected one of outdoor heat-exchangers. Various variations and combinations of the embodiments may be permitted so long as they are not counter to the aims of the invention.

[0054] As is apparent from the above description, an air conditioner according to the embodiments of the present disclosure may adjust capacity of an outdoor heat-exchanger unit based on low-load operating conditions using 4-way valves and expansion valves without using electronic on-off valves that have difficulty in keeping balance of pressure loss and cost. Further, when introduction of refrigerant into a second outdoor heat-exchanger stops, it may be possible to prevent refrigerant from a first connection line or a suction line from flowing backward through a second connection line using a check valve provided on the second connection line and from accumulating in the second outdoor heat-exchanger when the second outdoor heat-exchanger is stopped.

[0055] Although embodiments of the present invention 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 of the invention, the scope of which is defined in the claims.

Claims

1. An air conditioner comprising a refrigerant circuit constructed via annular connection of a compressor, a 4-way valve unit, an outdoor heat-exchanger unit, and an indoor heat-exchanger unit,
wherein the outdoor heat-exchanger unit is divided into a first outdoor heat-exchanger and a second outdoor heat-exchanger,
wherein the 4-way valve unit includes a first 4-way valve to switchably connect a gas line of the first outdoor heat-exchanger to any one of a discharge port or a suction port of the compressor, and a second 4-way valve to switchably connect a gas line of the second outdoor heat-exchanger to any one of the discharge port or the suction port of the compressor, and
wherein the air conditioner comprises
a first expansion valve provided on a liquid line of the first outdoor heat-exchanger;
a second expansion valve provided on a liquid line of the second outdoor heat-exchanger;
a first connection line to connect a suction line and one port of the first 4-way valve to each other, the suction line connecting the suction port of the compressor and the indoor heat exchanger unit to each other;
a second connection line to connect the suction line and one port of the second 4-way valve to each other; and
a check valve provided on the second connection line to allow flow of refrigerant only from the second 4-way valve to the suction line.

2. The air conditioner according to claim 1, further comprising:

   a pressure meter to measure discharge pressure and suction pressure of the compressor; and
   a valve controller to control at least the second 4-way valve and the second expansion valve,
   wherein, if a compression ratio that is a ratio of the discharge pressure to the suction pressure measured by the pressure meter is less than a predetermined compression ratio during cooling operation, the valve controller switches the second 4-way valve such that the gas line of the second outdoor heat-exchanger is connected to the suction port of the compressor, and the valve controller also closes the second expansion valve.

3. The air conditioner according to claim 2, wherein the valve controller closes the second expansion valve if the discharge pressure measured by the pressure meter is greater than a predetermined value during heating operation.

4. The air conditioner according to claim 1, wherein the 4-way valve unit further includes a main 4-way valve to switchably connect the indoor heat-exchanger unit to any one of the discharge port or the suction port of the compressor,
wherein the air conditioner further comprises
a first temperature sensor provided at the first out-

door heat-exchanger; a second temperature sensor provided at the second outdoor heat-exchanger;
a bypass line to connect the liquid line of the outdoor heat-exchanger unit and the suction line of the compressor to each other;
an auxiliary heat-exchanger provided on the bypass line to perform heat-exchange between refrigerant in the liquid line and refrigerant in the bypass line; and
an auxiliary expansion valve provided on a liquid line of the auxiliary heat-exchanger of the bypass line,
wherein the valve controller is configured to control the first 4-way valve, the main 4-way valve and the auxiliary expansion valve, and
wherein, if temperature detected by the first temperature sensor or the second temperature sensor is equal to or less than a predetermined value during heating operation in which the indoor heat-exchanger unit is connected to the discharge port of the compressor, the valve controller switches the first 4-way valve or the second 4-way valve such that the gas line of the first outdoor heat-exchanger or the second outdoor heat-exchanger is connected to the discharge port of the compressor while maintaining the main 4-way valve to connect the indoor heat-exchanger unit and the discharge port of the compressor to each other, thereby allowing gas-phase refrigerant to be introduced into the first outdoor heat-exchanger or the second outdoor heat-exchanger, and the valve controller also opens the auxiliary expansion valve to allow liquid-phase refrigerant to be evaporated by the auxiliary heat-exchanger and gas-phase refrigerant to return to the suction line.

5. The air conditioner according to claim 2, wherein the 4-way valve unit further includes a main 4-way valve to switchably connect the indoor heat-exchanger unit to any one of the discharge port or the suction port of the compressor,
wherein the air conditioner further comprises
a first temperature sensor provided at the first outdoor heat-exchanger; a second temperature sensor provided at the second outdoor heat-exchanger;
a bypass line to connect the liquid line of the outdoor heat-exchanger unit and the suction line of the compressor to each other;
an auxiliary heat-exchanger provided on the bypass line to perform heat-exchange between refrigerant in the liquid line and refrigerant in the bypass line; and
an auxiliary expansion valve provided on a liquid line of the auxiliary heat-exchanger of the bypass line,
wherein the valve controller is configured to control the first 4-way valve, the main 4-way valve and the auxiliary expansion valve, and
wherein, if temperature detected by the first temperature sensor or the second temperature sensor is equal to or less than a predetermined value during heating operation in which the indoor heat-exchanger unit is connected to the discharge port of the compressor, the valve controller switches the first 4-way valve or the second 4-way valve such that the gas line of the first outdoor heat-exchanger or the second outdoor heat-exchanger is connected to the discharge port of the compressor while maintaining the main 4-way valve to connect the indoor heat-exchanger unit and the discharge port of the compressor to each other, thereby allowing gas-phase refrigerant to be introduced into the first outdoor heat-exchanger or the second outdoor heat-exchanger, and the valve controller also opens the auxiliary expansion valve to allow liquid-phase refrigerant to be evaporated by the auxiliary heat-exchanger and gas-phase refrigerant to return to the suction line.

6. The air conditioner according to claim 3, wherein the 4-way valve unit further includes a main 4-way valve to switchably connect the indoor heat-exchanger unit to any one of the discharge port or the suction port of the compressor,
wherein the air conditioner further comprises
a first temperature sensor provided at the first outdoor heat-exchanger; a second temperature sensor provided at the second outdoor heat-exchanger;
a bypass line to connect the liquid line of the outdoor heat-exchanger unit and the suction line of the compressor to each other;
an auxiliary heat-exchanger provided on the bypass line to perform heat-exchange between refrigerant in the liquid line and refrigerant in the bypass line; and
an auxiliary expansion valve provided on a liquid line of the auxiliary heat-exchanger of the bypass line,
wherein the valve controller is configured to control the first 4-way valve, the main 4-way valve and the auxiliary expansion valve, and
wherein, if temperature detected by the first temperature sensor or the second temperature sensor is equal to or less than a predetermined value during heating operation in which the indoor heat-exchanger unit is connected to the discharge port of the compressor, the valve controller switches the first 4-way valve or the second 4-way valve such that the gas line of the first outdoor heat-exchanger or the second outdoor heat-exchanger is connected to the discharge port of the compressor while maintaining the main 4-way valve to connect the indoor heat-exchanger unit and the discharge port of the compressor to each other, thereby allowing gas-phase refrigerant to be introduced into the first outdoor heat-exchanger or the second outdoor heat-exchanger, and the valve controller also opens the auxiliary expansion valve to allow liquid-phase refrigerant to be evaporated by the auxiliary heat-exchanger and gas-phase refrigerant to return to the suction line.

7. An air conditioner comprising:

a compressor;

a 4-way valve unit including a first 4-way valve and a second 4-way valve;
an outdoor heat-exchanger unit including a first outdoor heat-exchanger and a second outdoor heat-exchanger; and
an indoor heat-exchanger unit,
wherein the first 4-way valve is configured to switchably connect a gas line of the first outdoor heat-exchanger to any one of a discharge port or a suction port of the compressor, and
the second 4-way valve is configured to switchably connect a gas line of the second outdoor heat-exchanger to any one of the discharge port or the suction port of the compressor.

8. The air conditioner according to claim 7, further comprising:

a first expansion valve provided on a liquid line of the first outdoor heat-exchanger;
a second expansion valve provided on a liquid line of the second outdoor heat-exchanger;
a first connection line to connect a suction line and one port of the first 4-way valve to each other, the suction line connecting the suction port of the compressor and the indoor heat exchanger unit to each other;
a second connection line to connect the suction line and one port of the second 4-way valve to each other; and
a check valve provided on the second connection line to allow flow of refrigerant only from the second 4-way valve to the suction line.

9. The air conditioner according to claim 7, wherein the suction line includes a plurality of suction lines that connect the suction port of the compressor and the indoor heat-exchanger unit to each other.

10. The air conditioner according to claim 7, wherein the suction port of the compressor is connected to an accumulator via a single line and the accumulator is connected to the indoor heat-exchanger unit via a single line, and
an additional member is connected between the suction port of the compressor and the indoor heat-exchanger unit.

11. The air conditioner according to claim 8, further comprising:

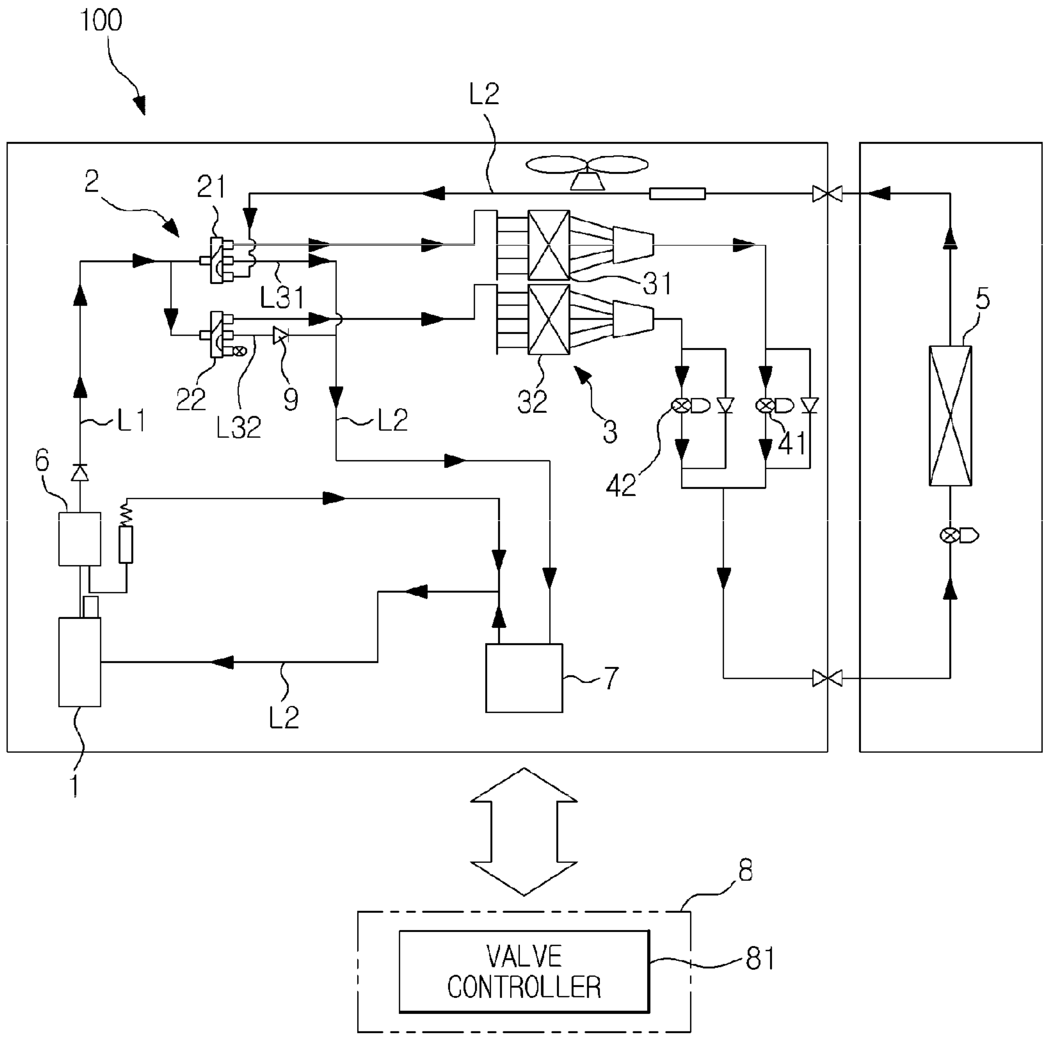
a pressure meter to measure discharge pressure and suction pressure of the compressor; and
a valve controller to control at least the second 4-way valve and the second expansion valve, and if a compression ratio that is a ratio of the discharge pressure to the suction pressure measured by the pressure meter is less than a predetermined compression ratio during cooling operation, the valve controller is configured to switch the second 4-way valve such that the gas line of the second outdoor heat-exchanger is connected to the suction port of the compressor, and the valve controller closes the second expansion valve.

12. The air conditioner according to claim 8, wherein the 4-way valve unit further comprises a main 4-way valve to switchably connect the indoor heat-exchanger unit to any one of the discharge port or the suction port of the compressor.

13. The air conditioner according to claim 12, further comprising:

a first temperature sensor provided at the first outdoor heat-exchanger;
a second temperature sensor provided at the second outdoor heat-exchanger;
a bypass line to connect the liquid line of the outdoor heat-exchanger unit and the suction line of the compressor to each other;
an auxiliary heat-exchanger provided on the bypass line to perform heat-exchange between refrigerant in the liquid line and refrigerant in the bypass line; and
an auxiliary expansion valve provided on a liquid line of the auxiliary heat-exchanger of the bypass line,
wherein the valve controller is configured to control the first 4-way valve, the main 4-way valve and the auxiliary expansion valve, and, if the temperature detected by the first temperature sensor or the second temperature sensor is equal to or less than a predetermined value during heating operation in which the indoor heat-exchanger unit is connected to the discharge port of the compressor, the valve controller is configured to switch the first 4-way valve or the second 4-way valve such that the gas line of the first outdoor heat-exchanger or the second outdoor heat-exchanger is connected to the discharge port of the compressor while maintaining the main 4-way valve to connect the indoor heat-exchanger unit and the discharge port of the compressor to each other, thereby allowing gas-phase refrigerant to be introduced into the first outdoor heat-exchanger or the second outdoor heat-exchanger, and
the valve controller is configured to open the auxiliary expansion valve to allow liquid-phase refrigerant to be evaporated by the auxiliary heat-exchanger and gas-phase refrigerant to return to the suction line.

FIG. 1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VALVE
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FIG. 2

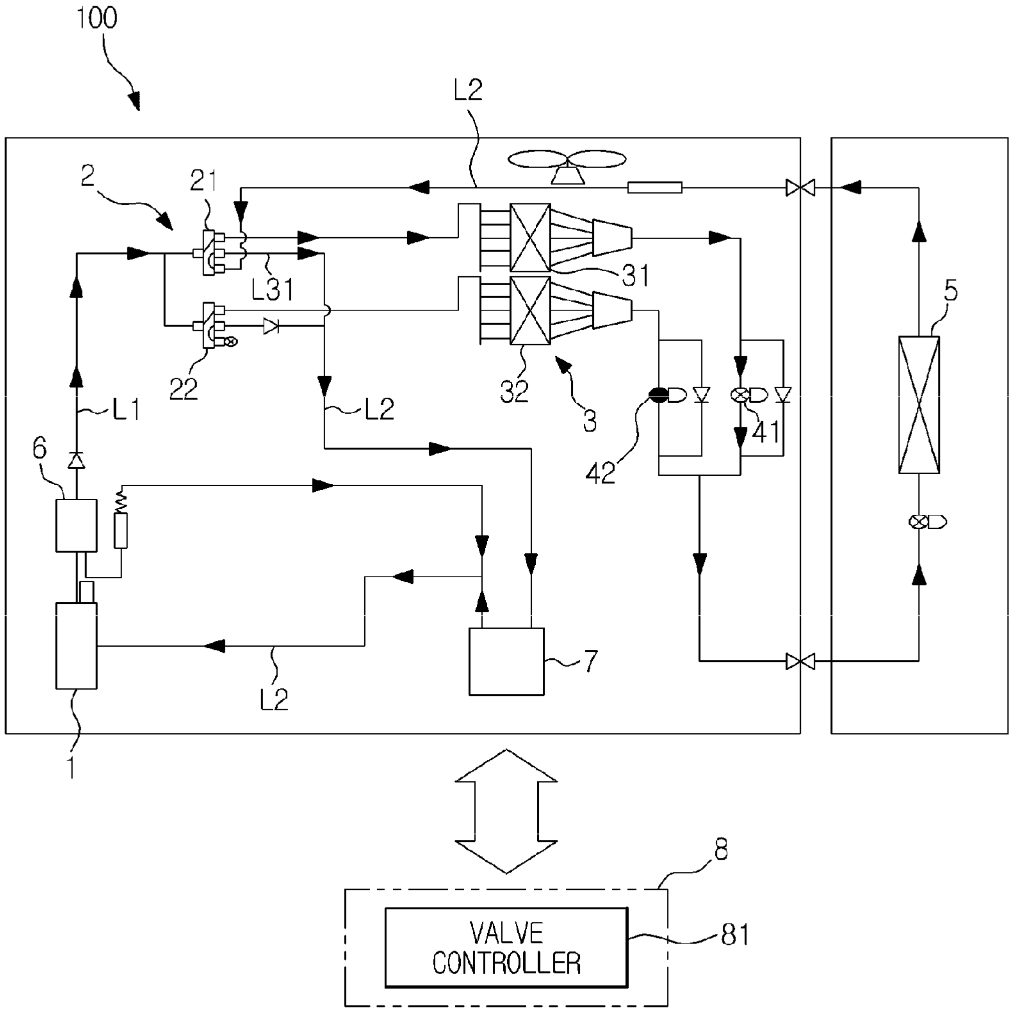
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FIG. 3

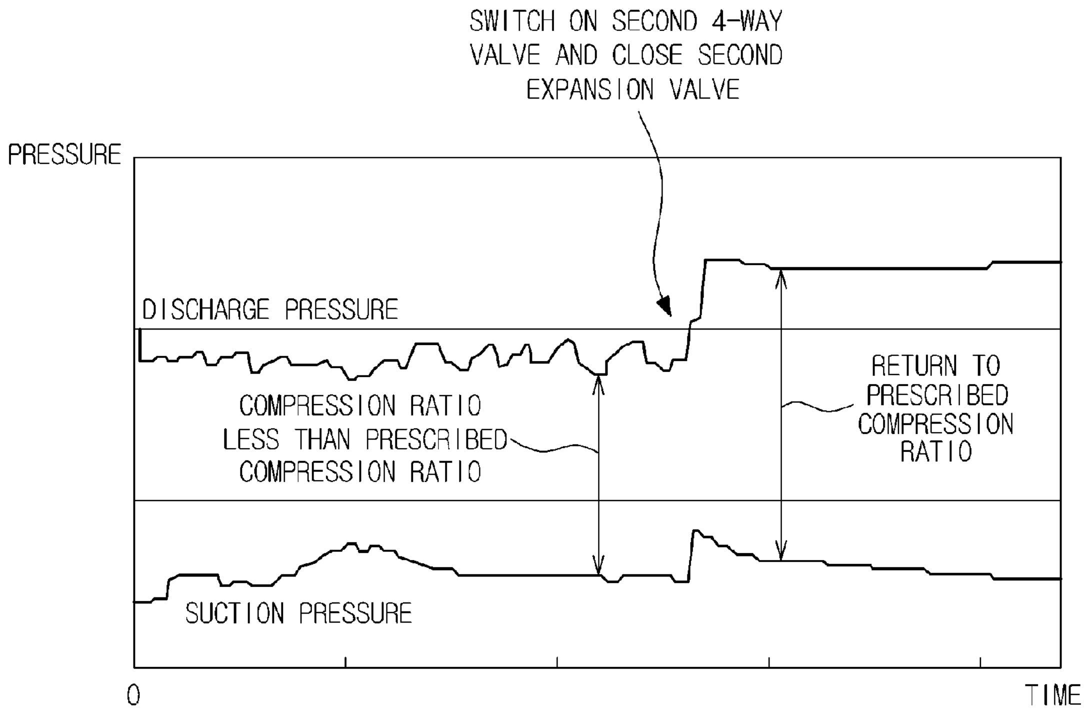
SWITCH ON SECOND 4-WAY VALVE AND CLOSE SECOND EXPANSION VALVE
PRESSURE
DISCHARGE PRESSURE
COMPRESSION RATIO LESS THAN PRESCRIBED COMPRESSION RATIO
RETURN TO PRESCRIBED COMPRESSION RATIO
SUCTION PRESSURE
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FIG. 4

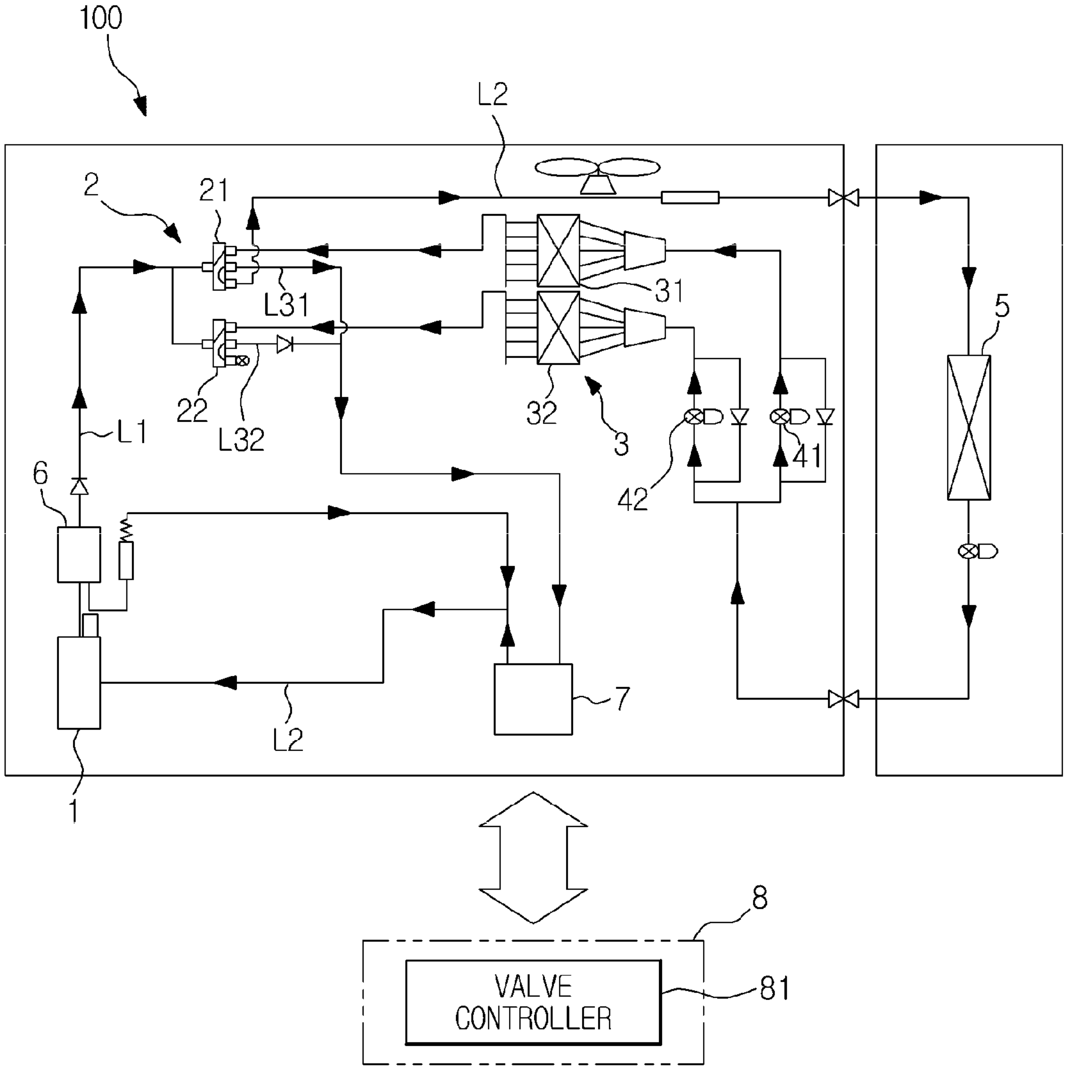
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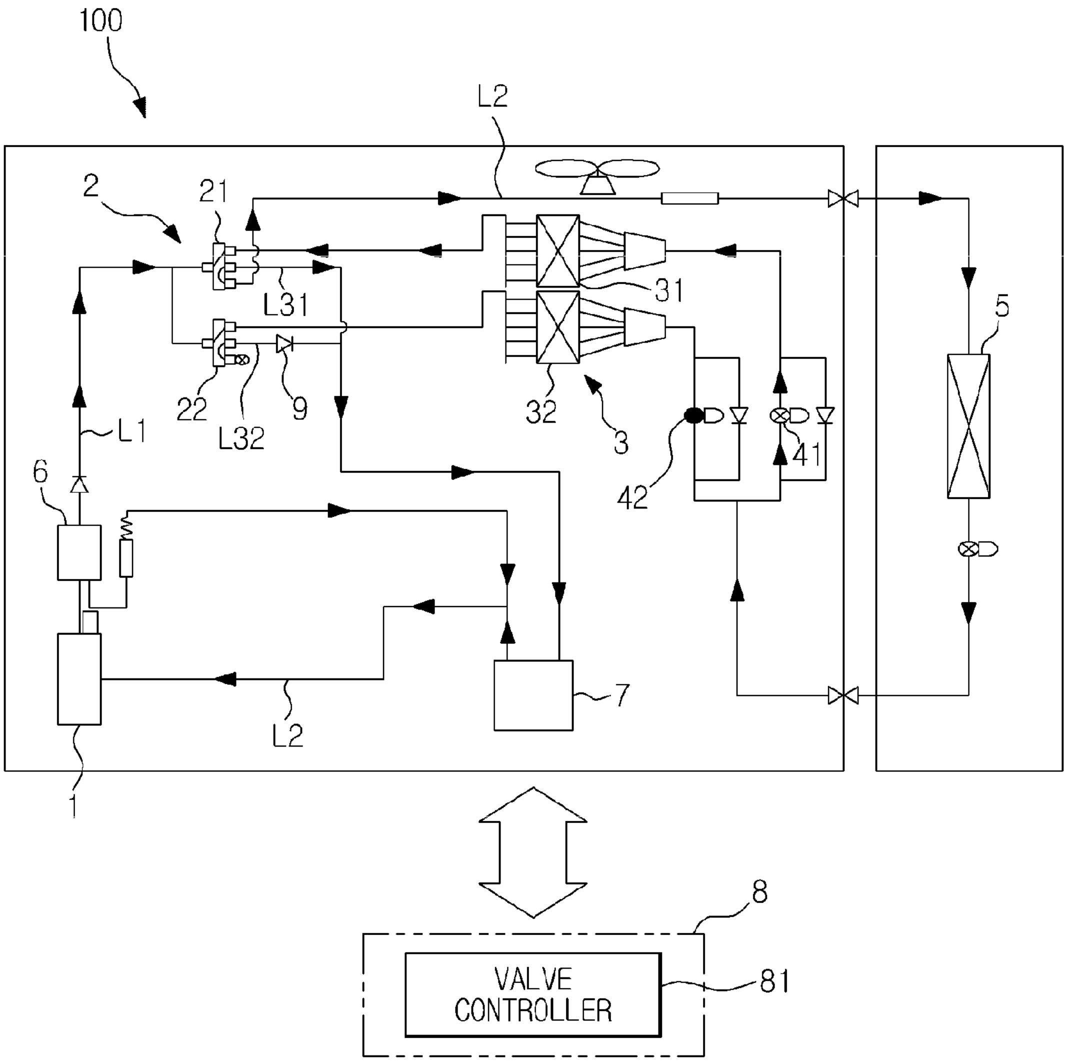
FIG. 5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VALVE
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FIG. 6A - Related Art

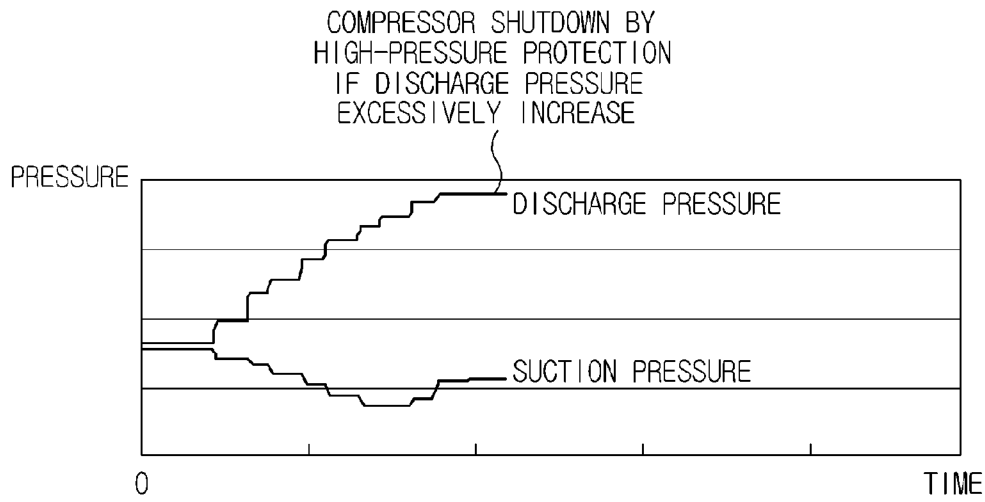


FIG. 6B

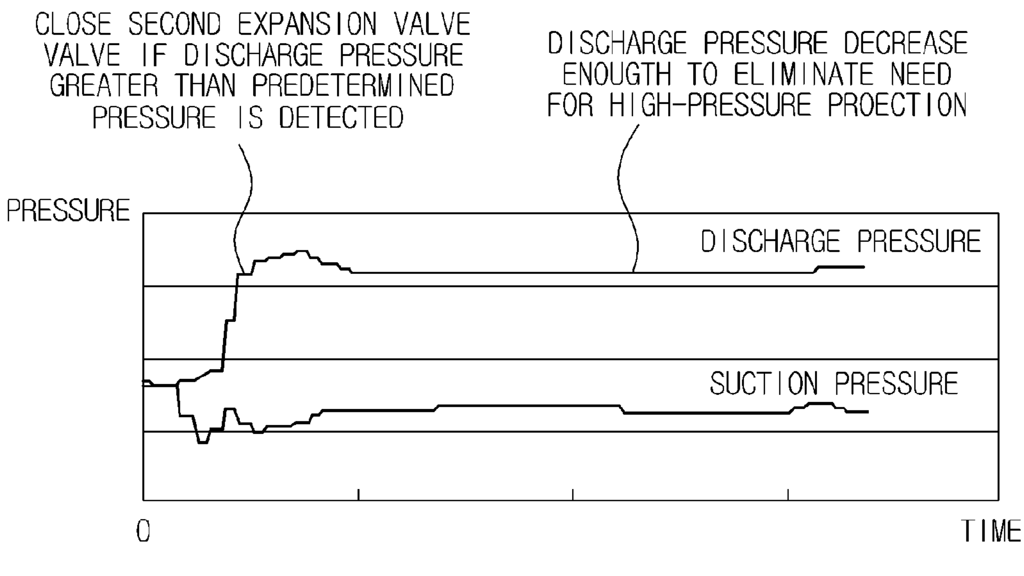
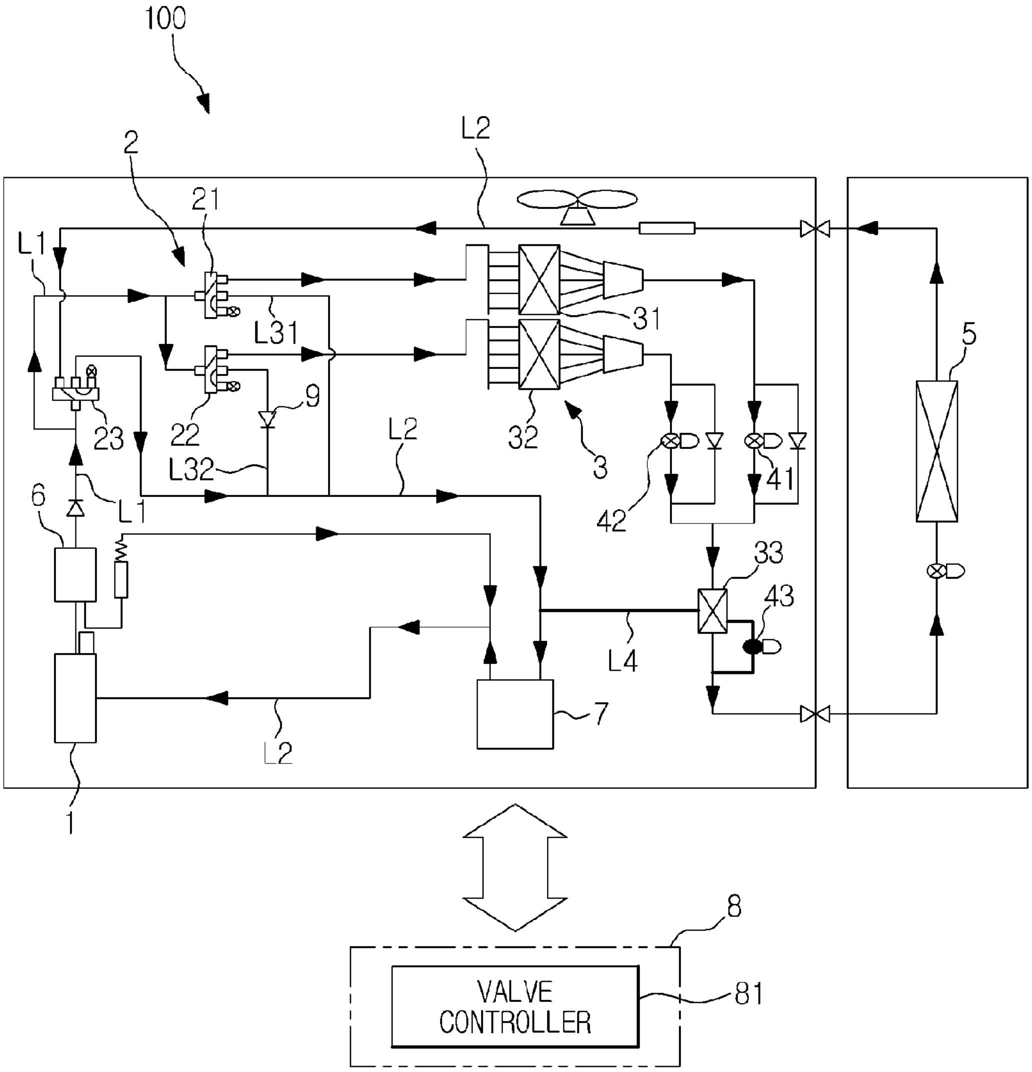


FIG. 7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VALVE
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FIG. 8

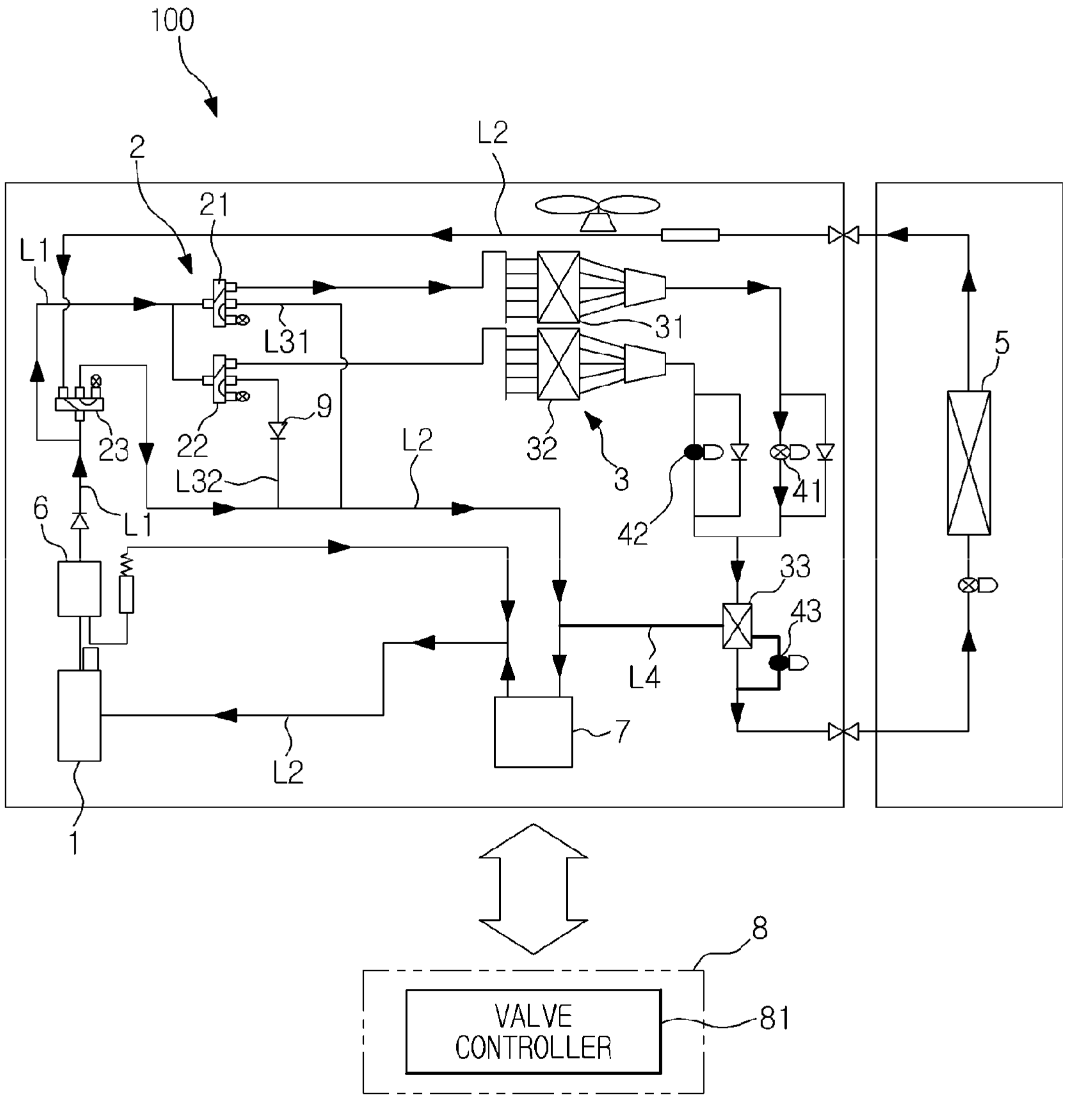
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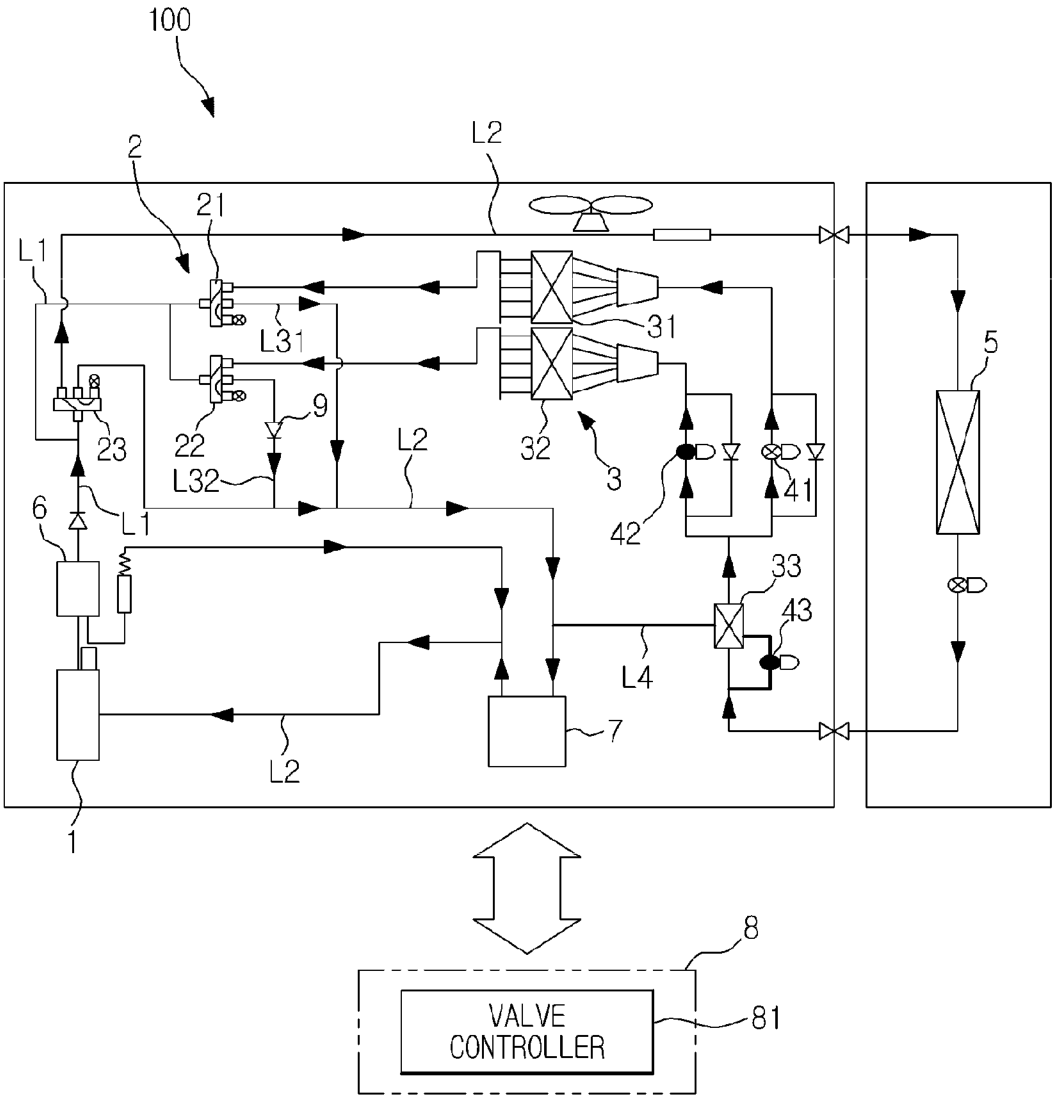
FIG. 9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VALVE CONTROLLER
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FIG. 10

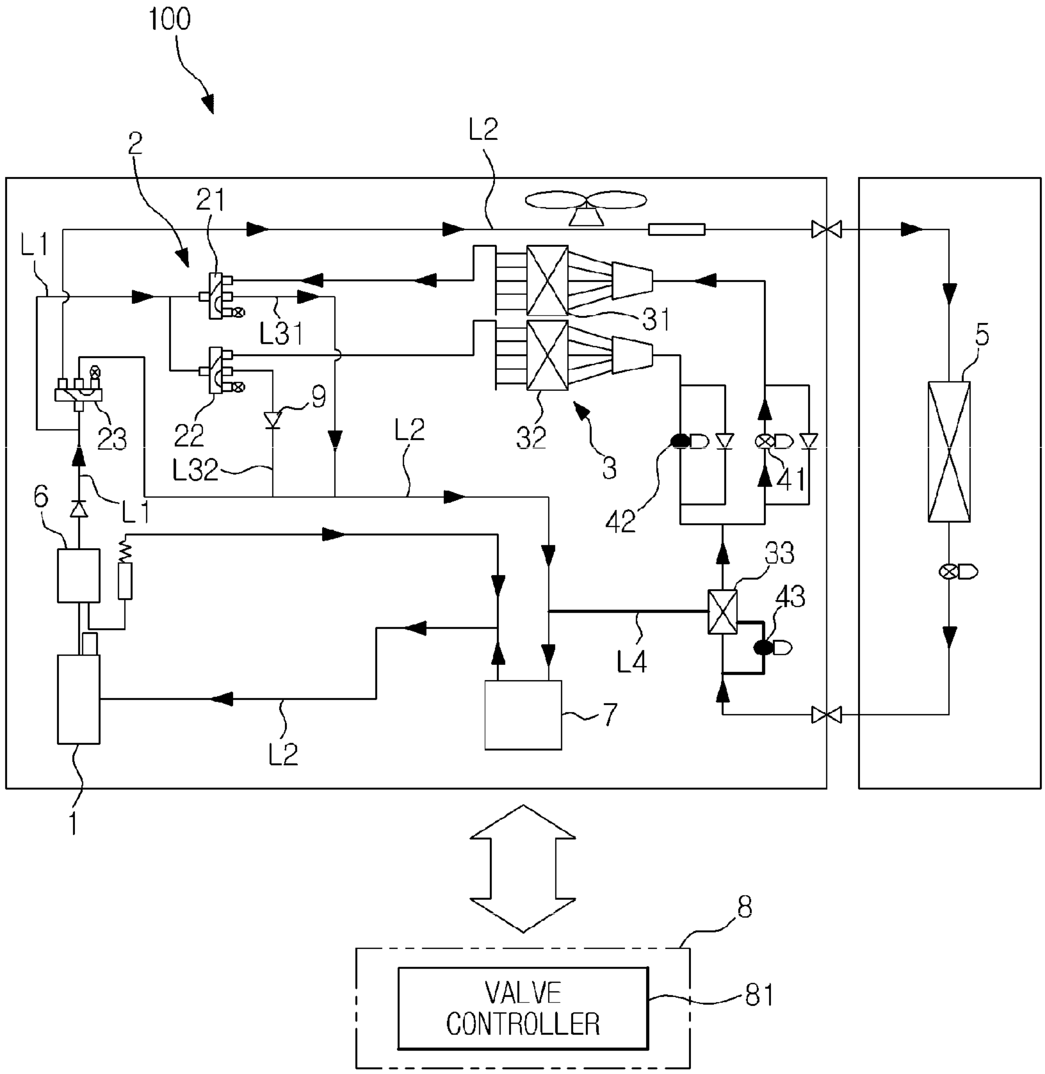
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FIG. 11

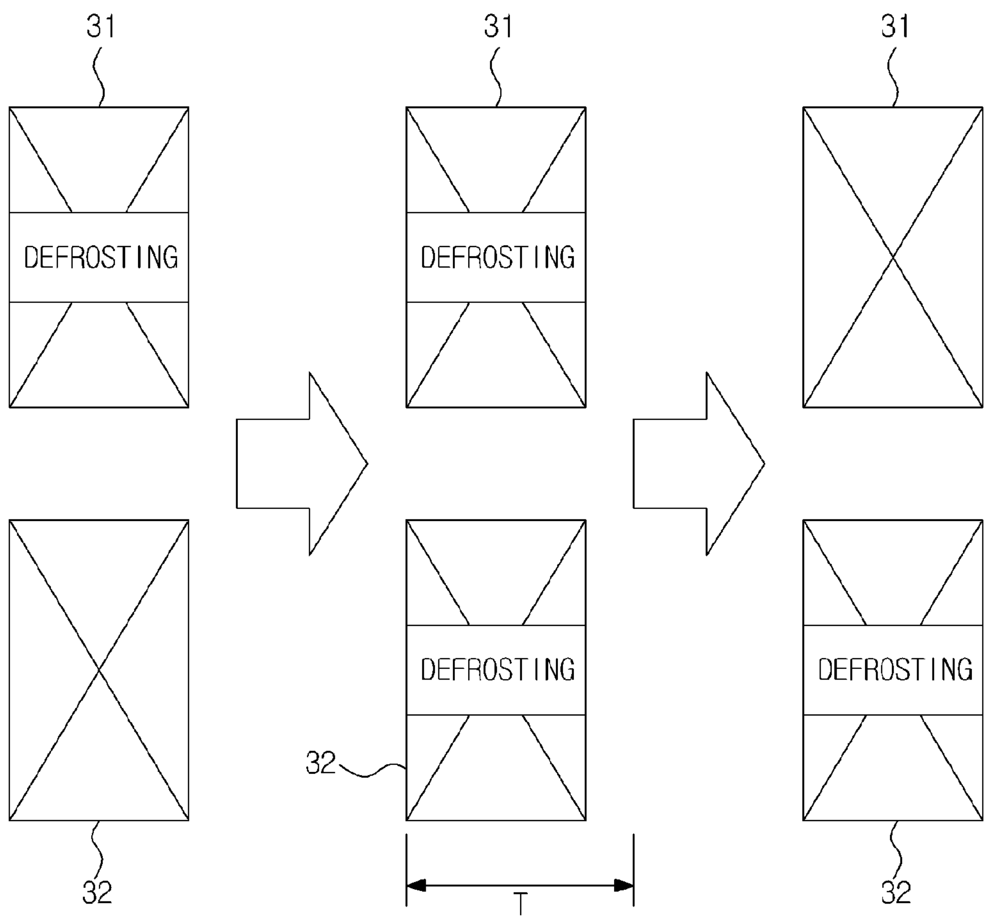
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FIG. 12

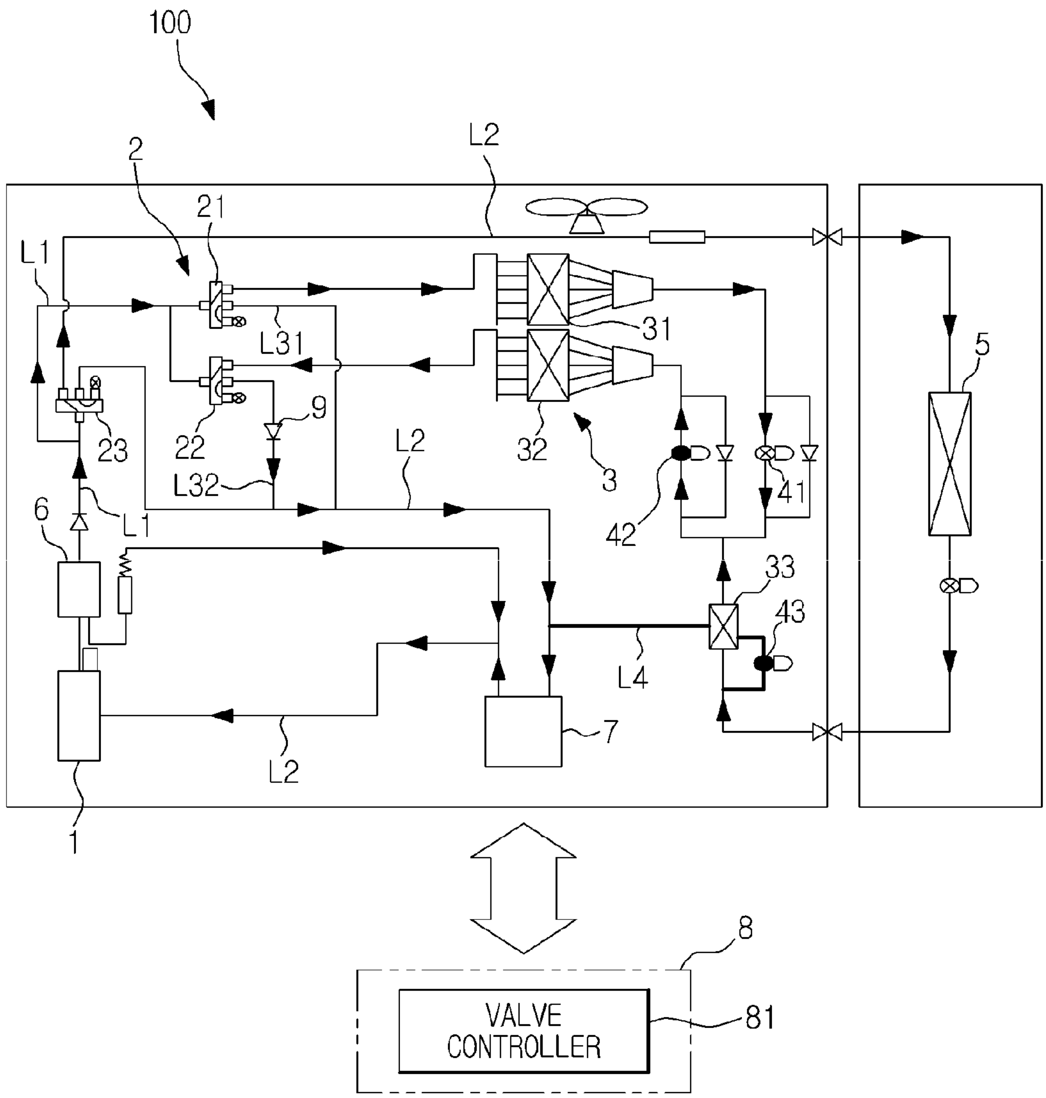
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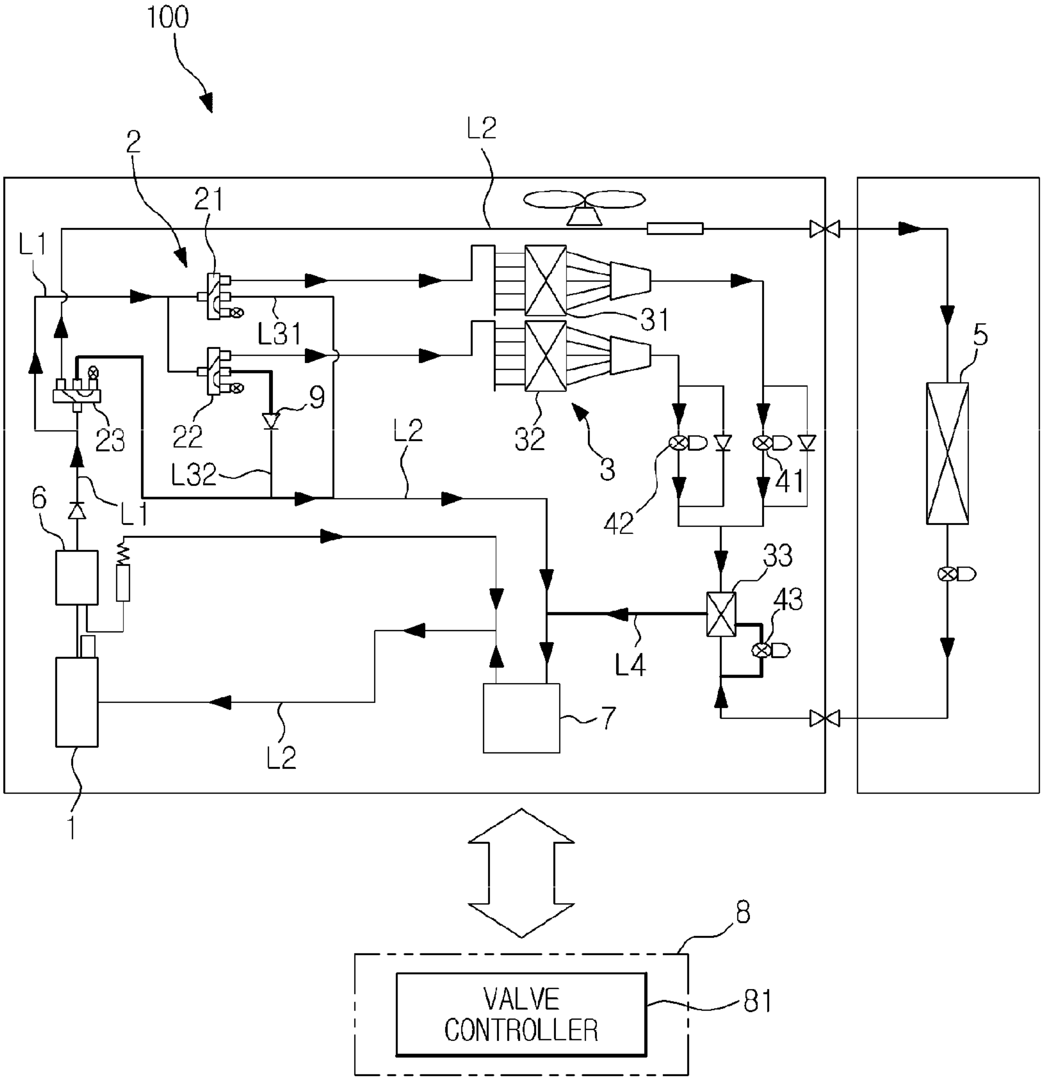
FIG. 13



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VALVE CONTROLLER
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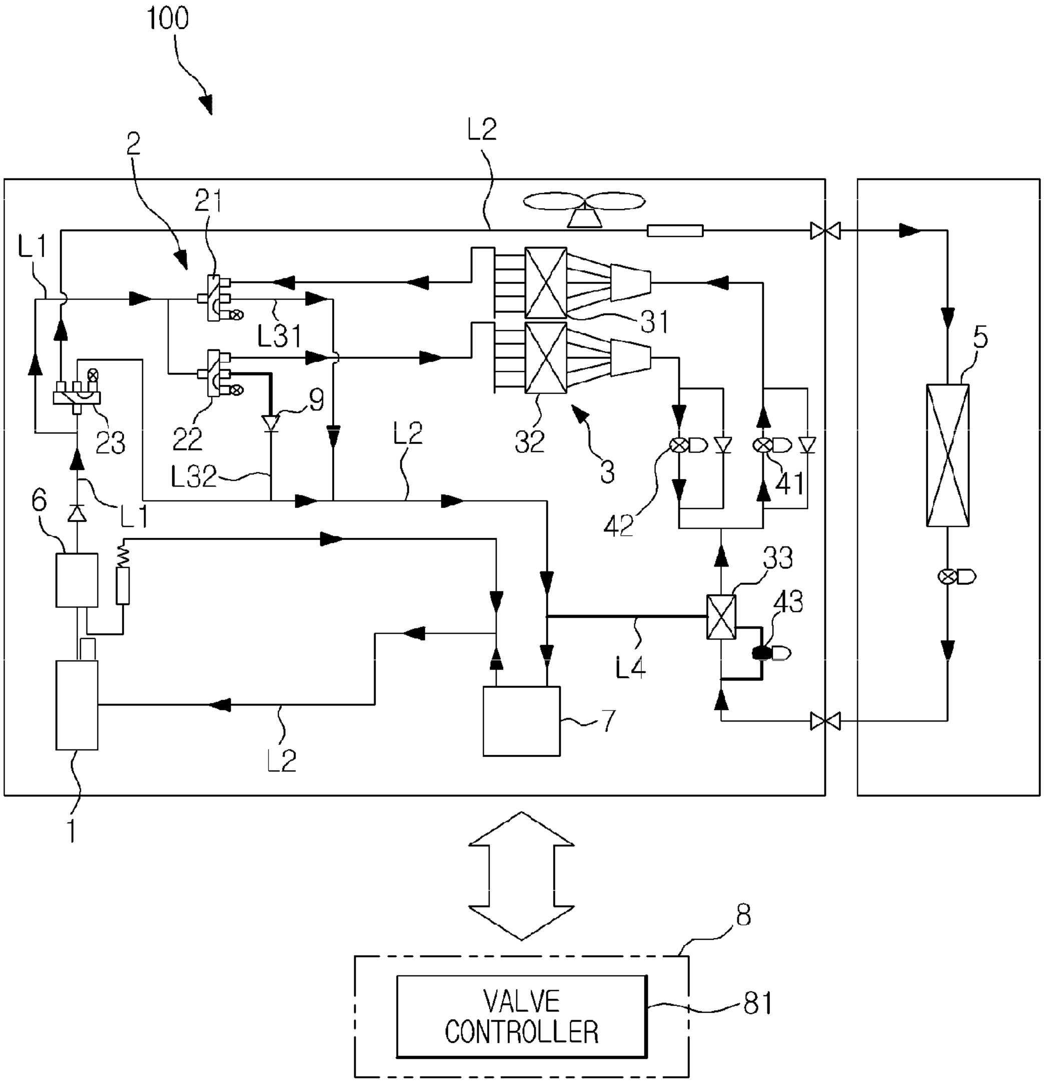
FIG. 14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VALVE
CONTROLLER
81

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PARTIAL EUROPEAN SEARCH REPORT

under Rule 62a and/or 63 of the European Patent Convention. This report shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number
EP 12 19 6569

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2008/059922 A1 (HITACHI APPLIANCES INC [JP]; NAITO KOJI [JP]; NAKAMURA KENICHI [JP]; U) 22 May 2008 (2008-05-22) * paragraph [0018] - paragraph [0054]; figure 2 * -----	1-6	INV. F25B13/00 F25B41/04 F25B47/02
A	US 5 159 817 A (HOJO TOSHIYUKI [JP] ET AL) 3 November 1992 (1992-11-03) * column 2 - column 6; figure 1 * -----	1-6	

TECHNICAL FIELDS SEARCHED (IPC)

F25B

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

1

Place of search	Date of completion of the search	Examiner
Munich	16 July 2013	Amous, Moez

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04E07)

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INCOMPLETE SEARCH SHEET C

Application Number
EP 12 19 6569

Claim(s) completely searchable:
1-6

Claim(s) not searched:
7-13

Reason for the limitation of the search:

Rule 62a EPC

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 19 6569

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The members are as contained in the European Patent Office EDP file on
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16-07-2013

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP H59180251 B **[0004]**