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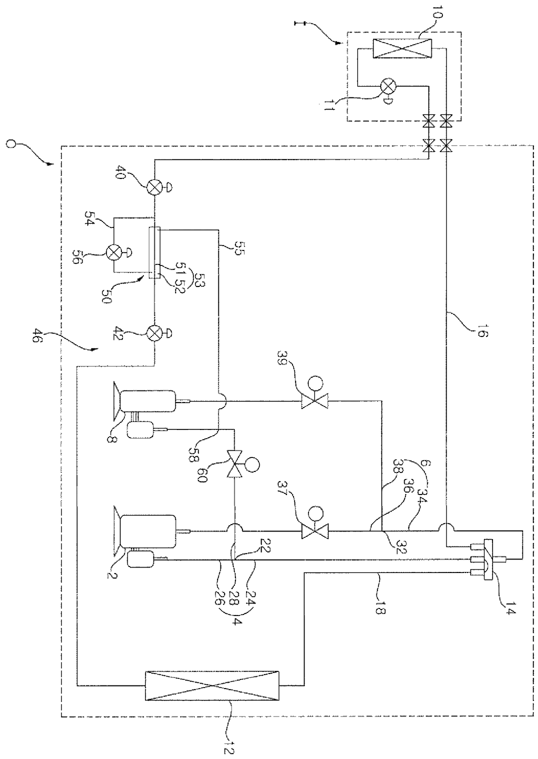
(54) Air conditioner

(57) Disclosed is an air conditioner including a plurality of compressors (2) (8) compressing a refrigerant, a first heat exchanger (10) for condensing the refrigerant compressed in the compressor (2), a first expansion valve (40) for expanding the condensed refrigerant, a second expansion valve (42) for expanding the refrigerant emerging from the first expansion valve (40), a second heat exchanger (12) for evaporating the refrigerant emerging from the second expansion valve (42). The refrigerant from the first expansion valve (40) is guided such that a portion of the refrigerant is introduced into one of the compressors (2) (8) after bypassing the second expansion valve (42) and second heat exchanger (12), and a remaining portion of the refrigerant is introduced into another one of the compressors (2)(8) after passing through the second expansion valve (42) and second heat exchanger (12), to minimize electric power consumption and to enhance heating performance.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The present invention relates to an air conditioner, and more particularly to an air conditioner having a plurality of compressors.

2. Description of the Related Art

[0002] Generally, an air conditioner is an appliance for cooling/heating a room or purifying air in the room, using a refrigeration cycle for a refrigerant, which is constituted by a compressor, a condenser, an expansion device, and an evaporator, in order to provide a more pleasant indoor environment.

[0003] Recently, an air conditioner, which includes a plurality of compressors for one outdoor unit, has been developed. In this case, one or more compressors may selectively operate in accordance with load. The plurality of compressors may include first and second compressors connected in parallel via a refrigerant suction line and a refrigerant discharge line.

[0004] At low load, only one of the first and second compressors operates. On the other hand, at high load, the first and second compressors operate simultaneously.

[0005] When the first and second compressors operate simultaneously, the refrigerant compressed in the first compressor and the refrigerant compressed in the second compressor sequentially pass through an indoor heat exchanger, an expansion device, and an outdoor heat exchanger, and are then distributed to the first and second compressors. The resultant refrigerant is sucked into the first and second compressors in a low-temperature and low-pressure state.

[0006] In such a conventional air conditioner, high electric power consumption and large refrigerant circulation amount are required because a low-temperature and low-pressure refrigerant is sucked into the first and second compressors.

SUMMARY OF THE INVENTION

[0007] Therefore, the present invention has been made in view of the above problems, and it is an object af the present invention to provide an air conditioner capable of optimally coping with a heating load, reducing electric power consumption, and achieving an increase in heating capacity.

[0008] In accordance with an aspect of the present invention, the above and other objects can be accomplished by the provision of an air conditioner including a first compressor, a second compressor connected to the first compressor in parallel by a refrigerant suction line and a refrigerant discharge line, a first heat exchanger for evaporating a refrigerant in a cooling mode, and condensing the refrigerant in a heating mode, a second heat exchanger for condensing the refrigerant in the cooling mode, and evaporating the refrigerant in the heating mode, a first expansion valve arranged between the first heat exchanger and the second heat exchanger, a second expansion valve arranged between the first expansion valve and the second heat exchanger, a bypass device connected between a branching point of the refrigerant suction line and the second compressor, to guide a portion of the refrigerant, which emerges from the first expansion valve, to flow to a point between the branching point of the refrigerant suction line and the second compressor after bypassing the second expansion valve and the second heat exchanger, and a one-way valve arranged between the branching point of the refrigerant suction line and a connecting point of the bypass device to the refrigerant suction line, to prevent the refrigerant, which emerges from the bypass device, from flowing to the branching point of the refrigerant suction line.

[0009] The second compressor may have a smaller displacement than the first compressor.

[0010] The first compressor may be a variable displacement compressor, and the second compressor may be a constant speed compressor.

[0011] The air conditioner may have a second compressor operation mode in which the second compressor operates alone, and the refrigerant, which emerges from the first expansion valve, flows to the second compressor after passing through the second expansion valve and the second heat exchanger, and a first and second compressor simultaneous operation mode in which the first compressor and the second compressor operate simultaneously, and a portion of the refrigerant, which emerges from the first expansion valve, to flow to the second compressor after bypassing the second expansion valve and the second heat exchanger, whereas a remaining portion of the refrigerant, which emerges from the first expansion valve, to flow to the first compressor after passing through the second expansion valve and the second heat exchanger.

[0012] The air conditioner may selectively perform the second compressor operation mode and the first and second compressor simultaneous operation mode.

[0013] The air conditioner may further have a first compressor operation mode in which the first compressor operates alone, and the refrigerant, which emerges from the first expansion valve, flows to the first compressor after passing through the second expansion valve and the second heat exchanger.

[0014] The air conditioner may selectively perform the second compressor operation mode, the first and second compressor simultaneous operation mode, and the first compressor operation mode.

[0015] The bypass device may include an inner heat exchanger having a first passage for guiding the refrigerant to flow between the first expansion valve and the second expansion valve, and a second passage, through which the refrigerant passes while exchanging heat with the refrigerant, which passes through the first passage, a first bypass passage having an end connected between the first passage of the inner heat exchanger and the first expansion valve, and an opposite end connected to the second passage, and a second bypass passage having an end connected to the second passage, and an opposite end connected to a suction line of the second compressor.

[0016] The bypass device may further include a third expansion valve arranged in the first bypass passage.

[0017] The third expansion valve may have a smaller capacity than the first expansion valve and the second expansion valve.

[0018] At a partial heating load, the second compressor may operate, the first compressor may be in a stopped state, and the third expansion valve may be closed. At a full heating load, the first compressor and the second compressor may operate, and the third expansion valve may be opened.

[0019] The bypass device may include a gas/liquid separator arranged between the first expansion valve and the second expansion valve, and a gas/liquid separator connecting passage having an end connected to the gas/liquid separator, and an opposite end connected to a suction line of the second compressor, to guide a gas portion of the refrigerant from the gas/liquid separator to flow to the suction line of the second compressor.

[0020] The bypass device may further include a third expansion valve arranged in the gas/liquid separator connecting passage.

[0021] The third expansion valve may have a smaller capacity than the first expansion valve and the second expansion valve.

[0022] At a partial heating load, the second compressor may operate, the first compressor may be in a stopped state, and the third expansion valve may be closed. At a full heating load, the first compressor and the second compressor may operate, and the third expansion valve may be opened.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagram illustrating a refrigeration cycle in an air conditioner according to an exemplary embodiment of the present invention;

FIG. 2 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the embodiment of the present invention illustrated in FIG. 1 when a first compressor operates alone;

FIG. 3 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the embodiment of the present invention illustrated in FIG. 1 when a second compressor operates alone;

FIG. 4 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the embodiment of the present invention illustrated in FIG. 1 when the first and second compressors operate simultaneously;

FIG. 5 is a P-h diagram according to operation modes of a plurality of compressors in the embodiment of the present invention illustrated in FIG. 1;

FIG. 6 is a diagram illustrating a refrigeration cycle in an air conditioner according to another exemplary embodiment of the present invention;

FIG. 7 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the embodiment of the present invention illustrated in FIG. 6 when a first compressor operates alone;

FIG. 8 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the embodiment of the present invention illustrated in FIG. 6 when a second compressor operates alone;

FIG. 9 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the embodiment of the present invention illustrated in FIG. 6 when the first and second compressors operate simultaneously; and

FIG. 10 is a P-h diagram according to operation modes of a plurality of compressors in the embodiment of the present invention illustrated in FIG. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Exemplary embodiments of the present invention will be described with reference to the attached drawings.

[0025] FIG. 1 is a diagram illustrating a refrigeration cycle in an air conditioner according to an exemplary embodiment of the present invention. FIG. 2 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the illustrated embodiment of the present invention when a first compressor operates alone. FIG. 3 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the illustrated embodiment of the present invention when a second compressor operates alone. FIG. 4 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the illustrated embodiment of the present invention when the first and second compressors operate simultaneously. FIG. 5 is a P-h diagram according to operation modes of a plurality of compressors in the illustrated embodiment of the present invention.

[0026] The air conditioner according to the illustrated embodiment includes a plurality of compressors for compressing a refrigerant, for example, compressors 2 and 8, a first heat exchanger 10 for condensing the refrigerant emerging from the compressors 2 and 8, a first expansion valve 40 for expanding the refrigerant condensed by the first heat exchanger 10, a second expansion valve 42 for expanding the refrigerant emerging from the first expansion valve 40, a second heat exchanger 12 for evaporating the refrigerant emerging from the second expansion valve 42, and a variable refrigerant line 46 for guiding the refrigerant emerging from the first expansion valve 40 to pass through the second expansion valve 42 and second heat exchanger 12, or to bypass the second expansion valve 42 and second heat exchanger 12.

[0027] The variable refrigerant line 46 may guide the refrigerant emerging from the first expansion valve 40 such that a portion of the refrigerant is introduced into one of the plural compressors, for example, the compressor 8, after bypassing the second expansion valve 42 and second heat exchanger 12, with the remaining portion of the refrigerant being introduced into another one of the plural compressors, for example, the compressor 2, or such that the entirety of the refrigerant emerging from the first expansion valve 40 is distributed to the plural compressors, namely, the compressors 2 and 8, after passing through the second expansion valve 42 and second heat exchanger 12.

[0028] The variable refrigerant line 46 may also guide the refrigerant emerging from the first expansion valve 40 such that the entirety of the refrigerant is introduced into one of the plural compressors 2 and 8, for example, the compressor 8, after passing through the second expansion valve 42 and second heat exchanger 12, such that the entirety of the refrigerant is introduced into another one of the plural compressors 2 and 8, for example, the compressor 2, after passing through the second expansion valve 42 and second heat exchanger 12, or such that the entirety of the refrigerant is distributed to the plural compressors 2 and 8 after passing through the second expansion valve 42 and second heat exchanger 12.

[0029] The plural compressors 2 and 8 may include two or three compressors. The following description will be given in conjunction with the case in which the plural compressors 2 and 8 include two compressors, namely, the first compressor 2, and the second compressor 8 connected to the first compressor 2 in parallel via a refrigerant suction line 4 and a refrigerant discharge line 6.

[0030] In accordance with operating conditions, namely, load, the first and second compressors 2 and 8 may operate simultaneously or only one of the first and second compressors 2 and 8 may operate.

[0031] The first and second compressors 2 and 8 may have the same displacement or different displacements.

[0032] Where the first and second compressors 2 and 8 have different displacements, it may be possible to operate only the compressor 8, which has a smaller displacement, to operate only the compressor 2, which has a greater displacement, or to simultaneously operate the compressors 2 and 8, in accordance with load. Thus, it is preferred that the first and second compressors 2 and 8 have different displacements.

[0033] The air conditioner may have a plurality of partial-load operation modes and a full-load operation mode, to meet various operating conditions including, for example, ambient temperature and desired room temperature.

[0034] The load of the air conditioner may include a first partial load acceptable by operation of a smaller displacement one of the first and second compressors 2 and 8 alone. The load of the air conditioner may also include a second partial load that cannot be accepted by operation of the smaller displacement one of the first and second compressors 2 and 8, but is acceptable by operation of a greater displacement one of the first and second compressors 2 and 8 alone. The load of the air conditioner may also include a full load that is acceptable by simultaneous operations of the first and second compressors 2 and 8, but cannot be accepted by operation of the greater displacement one of the first and second compressors 2 and 8 alone.

[0035] When the load of the air conditioner is not higher than the first partial load, a first partial-load operation mode, in which the smaller displacement one of the first and second compressors 2 and 8 operates alone, may be carried out. On the other hand, when the load of the air conditioner is higher than the first partial load, but not higher than a second partial load, a second partial-load operation mode, in which the greater displacement one of the first and second compressors 2 and 8 operates alone, may be carried out. In addition, when the load of the air conditioner is higher than the second partial load, a full-load operation mode, in which the first and second compressors 2 and 8 operate simultaneously, may be carried out.

[0036] Since a portion of the refrigerant emerging from the first expansion valve 40 may be compressed in the second compressor 8 after bypassing the second expansion valve 42 and second heat exchanger 12, it is preferred that the second compressor 8 have a smaller displacement than the first compressor 2. Accordingly, the following description will be given in conjunction with the case in which the second compressor 8 has a smaller displacement than the first compressor 2.

[0037] The first partial-load operation mode is a second compressor operation mode in which the second compressor 8 operates alone, and the refrigerant emerging from the first expansion valve 40 flows to the second compressor 8 after passing through the second expansion valve 42 and second heat exchanger 12, as shown in FIG. 2.

[0038] The second partial-load operation mode is a first compressor operation mode in which the first compressor 2 operates alone, and the refrigerant emerging from the first expansion valve 40 flows to the first compressor 2 after passing through the second expansion valve 42 and second heat exchanger 12, as shown in FIG. 3.

[0039] The full-load operation mode is a first and second compressor simultaneous operation mode in which the first and second compressors 2 and 8 operate simultaneously, and a portion of the refrigerant emerging from the first expansion valve 40 flows to the second compressor 8 after bypassing the second expansion valve 42 and second heat exchanger 12, whereas the remaining portion of the refrigerant emerging from the first expansion valve 40 flows to the first compressor 2 after bypassing the second expansion valve 42 and second heat exchanger 12, as shown in FIG. 4.

[0040] Where the air conditioner includes a cooling/heating switching valve 14, it may be possible to selectively perform a cooling mode or a heating mode. In the cooling mode, the cooling/heating switching valve 14 may guide the refrigerant compressed in at least one of the first and second compressors 2 and 8 to the second heat exchanger 12, and may guide the refrigerant evaporated in the first heat exchanger 10 to the compressor, which is in operation. In the heating mode, the cooling/heating switching valve 14 may guide the refrigerant compressed in at least one of the first and second compressors 2 and 8 to the first heat exchanger 10, and may guide the refrigerant evaporated in the second heat exchanger 12 to the compressor, which is in operation.

[0041] The cooling/heating switching valve 14 may be connected to the first and second compressors 2 and 8 via the refrigerant suction line 4 and refrigerant discharge line 6. The cooling/heating switching valve 14 may also be connected to the first heat exchanger 10 via a cooling/heating switching valve-first heat exchanger connecting line 16. In addition, the cooling/heating switching valve 14 may be connected to the second heat exchanger 12 via a cooling/heating switching valve-second heat exchanger connecting line 18.

[0042] The refrigerant suction line 4 may have a branching point 22 where the refrigerant emerging from the cooling/heating switching valve 14 is distributed to the first and second compressors 2 and 8. The refrigerant suction line 4 may include a common suction line 24 connected to the cooling/heating switching valve 14, and suction lines 26 and 28 branched from the common suction line 24. The suction line 26 may be a first compressor-side suction line for guiding the refrigerant flowing through the common suction line 24 to the first compressor 2. On the other hand, the suction line 28 may be a second compressor-side suction line for guiding the refrigerant flowing through the common suction line 24 to the second compressor 8.

[0043] The refrigerant discharge line 6 may have a joining point 32 where the refrigerant emerging from the first compressor 2 and the refrigerant emerging from the second compressor 8 are joined. The refrigerant discharge line 6 may include a common discharge line 34 connected to the cooling/heating switching valve 14, and discharge lines 36 and 38 joined to the common discharge line 34. The discharge line 36 may be a first compressor-side discharge line for guiding the refrigerant compressed in the first compressor 2 to the common discharge line 34. On the other hand, the discharge line 38 may be a second compressor-side discharge line for guiding the refrigerant compressed in the second compressor 8 to the common discharge line 34. A first discharge-side check valve 37 may be installed at the first compressor-side discharge line 36, to prevent the refrigerant compressed in the second compressor 8 from flowing to the first compressor 2. Also, a second discharge-side check valve 39 may be installed at the second compressor-side discharge line 38, to prevent the refrigerant compressed in the first compressor 2 from flowing to the second compressor 8.

[0044] The first heat exchanger 10 may evaporate the refrigerant in the cooling mode, and may condense the refrigerant in the heating mode. The first expansion valve 40 may be arranged between the first heat exchanger 10 and the second heat exchanger 12. In the heating mode, the first expansion valve 40 may expand the refrigerant, which flows toward a bypass device 50 after being condensed in the first heat exchanger 10. The first expansion valve 40 may include an electronic expansion valve (EEV) or linear expansion valve (LEV) , opening degree of which is adjustable. The bypass device 50 will be described later.

[0045] In the air conditioner, the first heat exchanger 10 may be installed in an indoor unit I, whereas the first compressor 2, second compressor 8, second heat exchanger 12, second expansion valve 42, first expansion valve 40, and variable refrigerant line 46 may be installed in an outdoor unit O.

[0046] An indoor expansion valve 11 may be installed in the indoor unit I, to expand the refrigerant flowing to the first heat exchanger 10 in the cooling mode. The indoor expansion valve 11 may include an EEV or LEV, opening degree of which is adjustable. In the cooling mode, the indoor expansion valve 11 expands the refrigerant passing through the second expansion valve 42 and first expansion valve 40. In the heating mode, the indoor expansion valve 11 is fully opened, to allow the refrigerant emerging from the first heat exchanger 10 to pass therethrough.

[0047] The bypass device 50 is included in the variable refrigerant line 46. In addition to the bypass device 50, the variable refrigerant line 46 may include a one-way valve 60. The bypass device 50 is arranged to guide a portion of the refrigerant emerging from the first expansion valve 40 in the heating mode to bypass the second expansion valve 42 and second heat exchanger 12, and thus to flow to a point between the branching point 22 of the refrigerant suction line 4 and the second compressor 8. The one-way valve 60 is arranged to prevent the refrigerant emerging from the bypass device 50 from flowing to the branching point 22 of the refrigerant suction line 4.

[0048] The bypass device 50 is a gas injection device for injecting refrigerant into the second compressor 8 under the condition that the refrigerant is in liquid phase. The bypass device 50 is connected between the branching point 22 of the refrigerant suction line 4 and the second compressor 8. The bypass device 50 is configured to allow the refrigerant to be introduced into the second compressor 8 in the heating mode under the condition that the refrigerant has low-temperature and low-pressure liquid-phase. The bypass device 50 allows the refrigerant to be introduced into the second compressor 8 under the condition that the refrigerant has an intermediate pressure lower than the condensation pressure of the first heat exchanger 10, but higher than the evaporation pressure of the second heat exchanger 12.

[0049] The bypass device 50 may include an inner heat exchanger 53 having a first passage 51 for guiding the refrigerant to flow between the second expansion valve 41 and the first expansion valve 40, and a second passage 52, through which a refrigerant flows while exchanging heat with the refrigerant in the first passage 51. The bypass device 50 may include a first bypass passage 54 having an end connected between the first passage 51 of the inner heat exchanger 53 and the second expansion valve 42, and an opposite end connected to the second passage 52.

[0050] The bypass device 50 may also include a second bypass passage 55 having an end connected to the second passage 52, and an opposite end connected to the suction line 28 of the second compressor 8.

[0051] The inner heat exchanger 53 may be arranged between the first expansion valve 40 and the second expansion valve 42, to allow the refrigerant emerging from the first expansion valve 40 to flow to the second expansion valve 42, and to allow the refrigerant emerging from the second expansion valve 42 to flow to the first expansion valve 40.

[0052] The bypass device 50 may further include a third expansion valve 56 installed in the first bypass passage 54. The third expansion valve 56 may include an LEV or EEV, opening degree of which is adjustable. The third expansion valve 56 has a smaller capacity than the first expansion valve 40 and second expansion valve 42. When the capacity of the third expansion valve 56 is greater than or equal to those of the first expansion valve 40 and second expansion valve 42, there is a high possibility of the refrigerant, which is in liquid phase, being introduced into the second compressor 8. In this case, it may also be difficult to finely adjust the pressure and temperature of the refrigerant introduced into the first bypass passage 54. On the other hand, when the capacity of the third expansion valve 56 is smaller than the first expansion valve 40 and second expansion valve 42, it may be possible to minimize the possibility of the refrigerant, which is in liquid phase, being introduced into the second compressor 8. In this case, it may also be possible to more finely adjust the pressure and temperature of the refrigerant introduced into the first bypass passage 54. The third expansion valve 56 may control the refrigerant introduced into the first bypass passage 54 to have a pressure lower than the condensation pressure of the first heat exchanger 10, but higher than the evaporation pressure of the second heat exchanger 12. The third expansion valve 56 may be closed in the cooling mode, irrespective of the load of the air conditioner. In a full-load heating mode, the third expansion valve 56 may be opened to a predetermined opening degree, in order to allow the refrigerant to be introduced into the second compressor 8 after passing through the bypass device 50. On the other hand, in a partial-load heating mode, the third expansion valve 56 may be closed to prevent the refrigerant from passing through the bypass device 50.

[0053] The one-way valve 60 is arranged between the branching point 22 of the refrigerant suction line 4 and a connecting point 58 of the bypass device 50 to the refrigerant suction line 4. The one-way valve 60 may include a check valve, which guides the refrigerant passing through the branching point 22 of the refrigerant suction line 4 to flow to the second compressor 8, while preventing the refrigerant emerging from the bypass device 50 from flowing to the first compressor 2.

[0054] The air conditioner may be configured to diversely control the first compressor 2, second compressor 8 and third expansion valve 56, in accordance with heating load.

[0055] When the air conditioner is in a heating mode, and the load thereof is the first-partial load or second-partial load, the air conditioner may be controlled such that the second compressor 8 operates, the first compressor 2 is in a stopped state, and the third expansion valve 56 is closed.

[0056] On the other hand, when the air conditioner is in a heating mode, and the load thereof is the full load, the air conditioner may be controlled such that the first and second compressors 2 and 8 operate, and the third expansion valve 56 is opened.

[0057] Each of the first and second compressors 2 and 8 may be a constant speed compressor, which compresses a refrigerant at constant speed. Each of the first and second compressors 2 and 8 may be a variable displacement compressor such as a variable displacement inverter compressor. Alternatively, one of the first and second compressors 2 and 8 may be a constant speed compressor, whereas the other one of the first and second compressors 2 and 8 may be a variable displacement compressor.

[0058] Where one of the first and second compressors 2 and 8 is a variable displacement compressor, and the other one of the first and second compressors 2 and 8 is a constant speed compressor, it may be possible to more diversely cope with load.

[0059] Where the first compressor 2 is a variable displacement compressor, and the second compressor 8 is a constant speed compressor, it may be possible to selectively perform the second compressor operation mode or the first and second compressor simultaneous operation mode in accordance with the first partial load or full load, without performing one of the second compressor operation mode, first compressor operation mode, and first and second compressor simultaneous operation mode in accordance with the first partial load, second partial load, or full load.

[0060] That is, at a partial load not higher than the first partial load, only the second compressor 8 operates to cope with the partial load. At a load higher than the first partial load, but not higher than the full load, the second compressor 8 operates, and the first compressor 2 operates in a variable displacement mode to achieve load balancing. Accordingly, it may be possible to efficiently cope with a load higher than the first partial load as well as a load not higher than the first partial load, while minimizing electric power consumption.

[0061] For example, where the first compressor 2 is a 5HP variable displacement compressor, and the second compressor 8 is a 2HP constant speed compressor, the second compressor 8 may operate alone at a partial load corresponding to 2HP or smaller (namely, the second compressor operation mode). On the other hand, at a load corresponding to a displacement greater than 2HP, but not greater than 7HP (for example, 3HP, 4HP, 5HP, 6HP, or 7HP), the second compressor 8 operates (for 2HP), and the first compressor 2 operates in a variable displacement mode to achieve load balancing (1HP, 2HP, 3HP, 4HP, or 5HP) (namely, the first and second compressor simultaneous operation mode). In this case, the first and second compressors 2 and 8 may efficiently cope with a load up to 7HP.

[0062] On the other hand, where the first compressor 2 is a constant speed compressor, and the second compressor 8 is a variable displacement compressor, it may be possible to selectively perform one of the second compressor operation mode, first compressor operation mode, and first and second compressor simultaneous operation mode in accordance with the first partial load, second partial load, or full load.

[0063] For example, where the first compressor 2 is a 5HP constant speed compressor, and the second compressor 8 is a 2HP variable displacement compressor, the second compressor 8 may operate alone at a partial load corresponding to 2HP or lower (namely, the second compressor operation mode). At a partial load corresponding to a displacement greater than 2HP, but not greater than 5HP, the first compressor 2 operates alone, irrespective of the level of the load (namely, the first compressor operation mode). On the other hand, at a load corresponding to a displacement greater than 5HP, but not greater than 7HP (for example, 6HP or 7HP), the first compressor 2 operates (for 5HP), and the second compressor 8 operates in a variable displacement mode to achieve load balancing (1HP or 2HP) (namely, the first and second compressor simultaneous operation mode). In this case, the first and second compressors 2 and 8 may efficiently cope with a load of 0 to 2HP and a load of 5 to 7HP. Also, it may be possible to cope with a load corresponding to a displacement greater than 2HP, but not greater than 5HP.

[0064] Where the first compressor 2 is a variable displacement compressor, and the second compressor 8 is a constant speed compressor, it may be possible to more efficiently cope with the entirety of the load through the second compressor operation and the first and second compressor simultaneous operation. Accordingly, it is preferred that the first compressor 2 be a variable displacement compressor having a greater displacement than the second compressor 8, and the second compressor 8 be a constant speed compressor having a smaller displacement than the first compressor 2.

[0065] It may be possible to vary the volume ratio between the first and second compressors 2 and 8 by adjusting the operation frequency of the first compressor 2. Through the volume ratio variation, it may be possible to control an intermediate pressure, at which an optimal efficiency is obtained in accordance with operating conditions.

[0066] Where the first compressor 2 is a variable displacement compressor having a greater displacement than the second compressor 8, and the second compressor 8 is a constant speed compressor having a smaller displacement than the first compressor 2, a load acceptable by operation of the second compressor 8 alone may be set to the partial load, and a load acceptable by simultaneous operations of the first and second compressors 2 and 8 may be set to the full load. When the load of the air conditioner is a partial heating load, it is preferred that the second compressor 8 operate, the first compressor 2 be in a stopped state, and the third expansion valve 56 be closed. On the other hand, when the load is a full heating load, it is preferred that the first and second compressors 2 and 8 operate, and the third expansion valve 56 be opened.

[0067] Hereinafter, functions of the air conditioner configured as described above in accordance with the illustrated embodiment of the present invention will be described in detail.

[0068] When the air conditioner is in the heating mode and in the second compressor operation mode, in which the second compressor 8 operates alone, as shown in FIG. 2 and "A" of FIG. 5, the refrigerant, which is compressed in the second compressor 8 (a), may be condensed in the first heat exchanger 10 (b). The refrigerant may then be expanded in at least one of the first expansion valve 40 and second expansion valve 42 while passing through the first expansion valve 40, inner heat exchanger 53 and second expansion valve 42 (c). Thereafter, the refrigerant may be evaporated in the second heat exchanger 12 (d), and may then be returned to the second compressor 8 after passing through the one-way valve 60. The refrigerant may heat the first exchanger 10 while circulating the second compressor 8, first heat exchanger 10, first expansion valve 40, second expansion valve 42, second heat exchanger 12, one-way valve 60, and second compressor 8.

[0069] Since the second compressor 8 has a smaller displacement than the first compressor 2, the second compressor operation mode, in which the second compressor 8 operates alone, exhibits a lower compression work, a lower condensation pressure, and a higher evaporation pressure than the first compressor operation mode, in which the first compressor 2 operates alone, as shown in "A" and "B" of FIG. 5.

[0070] On the other hand, when the air conditioner is in the heating mode and in the first compressor operation mode, in which the first compressor 2 operates alone, as shown in FIG. 3 and "B" of FIG. 5, the refrigerant, which is compressed in the first compressor 2 (e), may be condensed in the first heat exchanger 10 (f). The refrigerant may then be expanded in at least one of the first expansion valve 40 and second expansion valve 42 while passing through the first expansion valve 40, inner heat exchanger 53, and second expansion valve 42 (g). Thereafter, the refrigerant may be evaporated in the second heat exchanger 12 (h), and may then be returned to the first compressor 2. The refrigerant may heat the first exchanger 10 while circulating the first compressor 2, first heat exchanger 10, first expansion valve 40, second expansion valve 42, and second heat exchanger 12.

[0071] When the air conditioner is in the heating mode and in the first-and second-compressor simultaneous operation mode, in which the first and second compressors 2 and 8 operate simultaneously, as shown in FIG. 4 and "C" and "D" of FIG. 5, the refrigerant, which is compressed in the first compressor 2 (i), and the refrigerant, which is compressed in the second compressor 8 (j), are joined. The joined refrigerant is condensed in the first heat exchanger 10 (k), and then passes through the first expansion valve 40.

[0072] A portion of the refrigerant passing trough the first expansion valve 40 flows to the first bypass passage 54, and then flows to the second bypass passage 55 after being expanded by the third expansion valve 56 (i), and passing through the second passage 52 of the inner heat exchanger 53 (m). The refrigerant flowing to the second bypass passage 55 is sucked into the second compressor 8 without being sucked into the first compressor 2 in accordance with the function of the one-way valve 60. The refrigerant is compressed in the second compressor 8 (j).

[0073] Meanwhile, the remaining portion of the refrigerant passing through the first expansion valve 40, namely, the refrigerant, which does not flow to the first bypass passage 54, exchanges heat with the refrigerant passing through the second passage 52 of the inner heat exchanger 58, while passing through the first passage 51 of the inner heat exchanger 53. Thereafter, this refrigerant is expanded by the second expansion valve (n), and is then evaporated in the second heat exchanger 12 (o). The evaporated refrigerant is sucked into the first compressor 2, and is then compressed (i).

[0074] In this case, the refrigerant may heat the first heat exchanger 10 while not only circulating the first compressor 2, first heat exchanger 10, first expansion valve 40, inner heat exchanger 53, second expansion valve 42, second heat exchanger 12, and first compressor 2 ("C" of FIG. 5), but also circulating the second compressor 8, first heat exchanger 10, first expansion valve 40, third expansion valve 56, inner heat exchanger 53, and second compressor 8 ("D" of FIG. 5).

[0075] It may be possible to introduce, into the first compressor 2, the refrigerant sequentially passing through the first expansion valve 40, inner heat exchanger 53, second expansion valve 42, and second heat exchanger 12, and to introduce, into the second compressor 8, the refrigerant sequentially passing through the first expansion valve 40, third expansion valve 56, and inner heat exchanger 53 while simultaneously operating the first and second compressors 2 and 8. Also, it may be possible not only to reduce electric power consumption, but also to increase the density of the refrigerant, thereby increasing the amount of the refrigerant circulating the air conditioner and enhancing the capacity of the refrigerant, as compared to the case in which the entirety of a low-temperature and low-pressure refrigerant is compressed by a single compressor, by controlling the pressure of the refrigerant such that the pressure of the refrigerant introduced into the second compressor 8 is higher than the pressure of the refrigerant introduced into the first compressor 2.

[0076] FIG. 6 is a diagram illustrating a refrigeration cycle in an air conditioner according to another exemplary embodiment of the present invention. FIG. 7 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the illustrated embodiment of the present invention when a first compressor operates alone. FIG. 8 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the illustrated embodiment of the present invention when a second compressor operates alone. FIG. 9 is a diagram illustrating a refrigerant flow in the refrigeration cycle in the air conditioner in the illustrated embodiment of the present invention when the first and second compressors operate simultaneously. FIG. 10 is a P-h diagram according to operation modes of a plurality of compressors in the illustrated embodiment of the present invention.

[0077] As shown in FIGS. 6 to 9, in the air conditioner according to this embodiment, the bypass device 50 may include a gas/liquid separator 62 arranged between the first expansion valve 40 and the second expansion valve 42. The bypass device 50 may include a gas/liquid separator connecting passage 64 having an end connected to the gas/liquid separator 62, and an opposite end connected to the suction line 28, in order to guide a gas-phase refrigerant emerging from the gas/liquid separator 62 to the suction line 28 of the second compressor 8. The configurations and functions of the air conditioner according to this embodiment, except for the bypass device, are identical or similar to those of the previous embodiment of the present invention. Accordingly, no description will be given of the identical or similar configurations and functions.

[0078] The gas/liquid separator 62 may separate liquid phase refrigerant and gas phase refrigerant from the refrigerant expanded by the first expansion valve 40. The gas/liquid separator 62 may be connected to the first expansion valve 40 by a first expansion valve connecting line, and may be connected to the second expansion valve 42 by a second expansion valve connecting line.

[0079] The bypass device 50 may further include a third expansion valve 66 installed at the gas/liquid separator connecting passage 64. The third expansion valve 66 may adjust the amount of the refrigerant flowing from the gas/liquid separator 62 to the gas/liquid separator connecting passage 64. The third expansion valve 66 may include an EEV or LEV, opening degree of which is adjustable. The third expansion valve 66 may be closed when the first compressor 2 operates alone, or the second compressor 8 operates alone, and may be opened only when the first and second compressors 2 and 8 operate simultaneously.

[0080] The third expansion valve 66 may have a smaller capacity than the first expansion valve 40 and second expansion valve 42. Where the capacity of the third expansion valve 66 is greater than or equal to those of the first expansion valve 40 and second expansion valve 42, there may be a high possibility of liquid phase refrigerant being introduced into the second compressor 8. In this case, it may also be difficult to finely adjust the pressure and temperature of the gas phase refrigerant emerging from the gas/liquid separator 62. On the other hand, when the third expansion valve 66 has a smaller capacity than the first expansion valve 40 and second expansion valve 42, it may be possible to minimize the possibility of the liquid phase refrigerant being introduced into the second compressor 8, and to more finely adjust the pressure and temperature of the gas phase refrigerant flowing to the first bypass passage 54.

[0081] When the air conditioner is in a heating mode and in a second compressor operation mode, in which the second compressor 8 operates alone, as shown in FIG. 7 and "A" of FIG. 10, the refrigerant, which is compressed in the second compressor 8 (a), may be condensed in the first heat exchanger 10 (b). The refrigerant may then be expanded in at least one of the first expansion valve 40 and second expansion valve 42 while passing through the first expansion valve 40, gas/liquid separator 62, and second expansion valve 42 (c). Thereafter, the refrigerant may be evaporated in the second heat exchanger 12 (d), and may then be returned to the second compressor 8 after passing through the one-way valve 60. The refrigerant may heat the first exchanger 10 while circulating the second compressor 8, first heat exchanger 10, first expansion valve 40, gas/liquid separator 62, second expansion valve 42, second heat exchanger 12, one-way valve 60, and second compressor 8.

[0082] Since the second compressor 8 has a smaller displacement than the first compressor 2, the second compressor operation mode, in which the second compressor 8 operates alone, exhibits a lower compression work, a lower condensation pressure, and a higher evaporation pressure than a first compressor operation mode, in which the first compressor 2 operates alone, as shown in "A" and "B" of FIG. 10.

[0083] On the other hand, when the air conditioner is in the heating mode and in the first compressor operation mode, in which the first compressor 2 operates alone, as shown in FIG. 8 and "B" of FIG. 10, the refrigerant, which is compressed in the first compressor 2 (e), may be condensed in the first heat exchanger 10 (f). The refrigerant may then be expanded in at least one of the first expansion valve 40 and second expansion valve 42 while passing through the first expansion valve 40, gas/liquid separator 62, and second expansion valve 42 (g) . Thereafter, the refrigerant may be evaporated in the second heat exchanger 12 (h), and may then be returned to the first compressor 2. The refrigerant may heat the first exchanger 10 while circulating the first compressor 2, first heat exchanger 10, first expansion valve 40, gas/liquid separator 62, second expansion valve 42, and second heat exchanger 12.

[0084] When the air conditioner is in the heating mode and in the first-and second-compressor simultaneous operation mode, in which the first and second compressors 2 and 8 operate simultaneously, as shown in FIG. 9 and "C" and "D" of FIG. 10, the refrigerant, which is compressed in the first compressor 2 (p), and the refrigerant, which is compressed in the second compressor 8 (q), are joined. The joined refrigerant is condensed in the first heat exchanger 10 (r), and then primarily expanded while passing through the first expansion valve 40 (s). The refrigerant primarily expanded by the first expansion valve 40 is introduced into the gas/liquid separator 62 which, in turn, separates the refrigerant into a gas phase refrigerant and a liquid phase refrigerant (t). The gas phase refrigerant from the gas/liquid separator 62 passes through the third expansion valve 66, and then flows to the suction line 28 of the second compressor 8. In the second compressor 8, the gas phase refrigerant is compressed (q). The liquid phase refrigerant from the gas/liquid separator 62 is secondarily expanded by the second expansion valve 42 (u), and is then evaporated in the second heat exchanger 12 (v). The evaporated refrigerant is sucked into the first compressor 2, and is then compressed (p).

[0085] In this case, the refrigerant may heat the first heat exchanger 10 while not only circulating the first compressor 2, first heat exchanger 10, first expansion valve 40, gas/liquid separator 62, second expansion valve 42, second heat exchanger 12, and first compressor 2 ("E" of FIG. 10), but also circulating the second compressor 8, first heat exchanger 10, first expansion valve 40, gas/liquid separator 62, third expansion valve 66, and second compressor 8 ("F" of FIG. 10).

[0086] It may be possible to introduce, into the first compressor 2, the refrigerant sequentially passing through the first expansion valve 40, gas/liquid separator 62, second expansion valve 42, and second heat exchanger 12, and to introduce, into the second compressor 8, the refrigerant sequentially passing through the first expansion valve 40, gas/liquid separator 62, and third expansion valve 56 while simultaneously operating the first and second compressors 2 and 8. Also, it may be possible not only to reduce electric power consumption, but also to increase the density of the refrigerant, thereby increasing the amount of the refrigerant circulating the air conditioner and enhancing the capacity of the refrigerant, as compared to the case in which the entirety of a low-temperature and low-pressure refrigerant is compressed by a single compressor, by controlling the pressure of the refrigerant such that the pressure of the refrigerant introduced into the second compressor 8 is higher than the pressure of the refrigerant introduced into the first compressor 2.

[0087] Where the first compressor 2 is a variable displacement compressor having a greater displacement than the second compressor 8, and the second compressor 8 is a constant speed compressor having a smaller displacement than the first compressor 2, as in the previous embodiment of the present invention, a load acceptable by operation of the second compressor 8 alone may be set to a partial load, and a load acceptable by simultaneous operations of the first and second compressors 2 and 8 may be set to a full load. When the load of the air conditioner is a partial heating load, it is preferred that the second compressor 8 operate, the first compressor 2 be in a stopped state, and the third expansion valve 56 be closed. On the other hand, when the load is a full heating load, it is preferred that the first and second compressors 2 and 8 operate, and the third expansion valve 56 be opened.

[0088] The air conditioner according to each embodiment of the present invention has the following advantages.

[0089] First, there are advantages in that it may be possible to minimize the amount of electric power consumed in all compressors of the air conditioner in a heating mode, as compared to the case in which the entirety of a low-temperature and low-pressure refrigerant is compressed by a single compressor, because the refrigerant compressed in the first compressor and the refrigerant compressed in the second compressor are sent to the first heat exchanger after being mixed, and a gas portion of the refrigerant primarily expanded by the first expansion valve is compressed in the second compressor after bypassing the second expansion valve and second heat exchanger, whereas a liquid portion of the refrigerant primarily expanded by the first expansion valve is compressed in the first compressor after passing through the second expansion valve and second heat exchanger.

[0090] Second, there are advantages in that, for a small heating load, the second compressor operates alone to cope with the small heating load, whereas, for a large heating load, the first and second compressors operate simultaneously to cope with the large heating load.

[0091] Third, there are advantages in that it may be possible to increase the density of the refrigerant, and to satisfy a required refrigerant capacity by the second compressor, which has a smaller displacement than the first compressor, as compared to the case in which the refrigerant is compressed in the second compressor under the condition that the refrigerant has a lower pressure than the refrigerant in a primarily expanded state, because only a gas portion of the primarily-expanded refrigerant is compressed in the second compressor.

[0092] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

Claims

1. An air conditioner comprising:

   a first compressor (2);
   a second compressor (8) connected to the first compressor (2) in parallel by a refrigerant suction line (4) and a refrigerant discharge line (6);
   a first heat exchanger (10) for evaporating a refrigerant in a cooling mode, and condensing the refrigerant in a heating mode;
   a second heat exchanger (12) for condensing the refrigerant in the cooling mode, and evaporating the refrigerant in the heating mode;
   a first expansion valve (40) arranged between the first heat exchanger (10) and the second heat exchanger (12);
   a second expansion valve (42) arranged between the first expansion valve (40) and the second heat exchanger (12);
   a bypass device (50) connected between a branching point (22) of the refrigerant suction line (4) and the second compressor (8), to guide a portion of the refrigerant, which emerges from the first expansion valve (40), to flow to a point between the branching point (22) of the refrigerant suction line (4) and the second compressor (8) after bypassing the second expansion valve (42) and the second heat exchanger (12); and
   a one-way valve (60) arranged between the branching point (22) of the refrigerant suction line (4) and a connecting point (58) of the bypass device (50) to the refrigerant suction line (4), to prevent the refrigerant, which emerges from the bypass device (50), from flowing to the branching point (22) of the refrigerant suction line (4).

2. The air conditioner according to claim 1, wherein the second compressor (8) has a smaller displacement than the first compressor (2).

3. The air conditioner according to claim 1 or 2, wherein the first compressor (2) is a variable displacement compressor, and the second compressor (8) is a constant speed compressor.

4. The air conditioner according to any of claims 1 to 3, wherein the air conditioner has:

a second compressor operation mode in which the second compressor (8) operates alone, and the refrigerant, which emerges from the first expansion valve (40), flows to the second compressor (8) after passing through the second expansion valve (42) and the second heat exchanger (12): and
a first and second compressor simultaneous operation mode in which the first compressor (2) and the second compressor (8) operate simultaneously, and a portion of the refrigerant, which emerges from the first expansion valve (40), to flow to the second compressor (8) after bypassing the second expansion valve (42) and the second heat exchanger (12), whereas a remaining portion of the refrigerant, which emerges from the first expansion valve (40), to flow to the first compressor (2) after passing through the second expansion valve (42) and the second heat exchanger (12).

5. The air conditioner according to claim 4, wherein the air conditioner selectively performs the second compressor operation mode and the first and second compressor simultaneous operation mode.

6. The air conditioner according to claim 4 or 5, wherein the air conditioner further has a first compressor operation mode in which the first compressor (2) operates alone, and the refrigerant, which emerges from the first expansion valve (40), flows to the first compressor (2) after passing through the second expansion valve (42) and the second heat exchanger (12).

7. The air conditioner according to claim 6, wherein the air conditioner selectively performs the second compressor operation mode, the first and second compressor simultaneous operation mode, and the first compressor operation mode.

8. The air conditioner according to any of claims 1 to 7, wherein the bypass device (50) comprises:

an inner heat exchanger (53) having a first passage (51) for guiding the refrigerant to flow between the first expansion valve (40) and the second expansion valve (42), and a second passage (52), through which the refrigerant passes while exchanging heat with the refrigerant, which passes through the first passage (51);
a first bypass passage (54) having an end connected between the first passage (51) of the inner heat exchanger (53) and the first expansion valve (40), and an opposite end connected to the second passage (52); and
a second bypass passage (55) having an end connected to the second passage (52), and an opposite end connected to a suction line of the second compressor (8).

9. The air conditioner according to claim 8, wherein the bypass device (50) further comprises a third expansion valve (56) arranged in the first bypass passage (54).

10. The air conditioner according to claim 9, wherein the third expansion valve (56) has a smaller capacity than the first expansion valve (40) and the second expansion valve (42).

11. The air conditioner according to claim 9 or 10, wherein:

at a partial heating load, the second compressor (8) operates, the first compressor (2) is in a stopped state, and the third expansion valve (56) is closed; and
at a full heating load, the first compressor (2) and the second compressor (8) operate, and the third expansion valve (56) is opened.

12. The air conditioner according to any of claims 1 to 7, wherein the bypass device (50) comprises:

a gas/liquid separator (62) arranged between the first expansion valve (40) and the second expansion valve (42); and
a gas/liquid separator connecting passage (64) having an end connected to the gas/iiquid separator (62), and an opposite end connected to a suction line of the second compressor (8), to guide a gas portion of the refrigerant from the gas/liquid separator (62) to flow to the suction line of the second compressor (8).

13. The air conditioner according to claim 12, wherein the bypass device (50) further comprises a third expansion valve (66) arranged in the gas/liquid separator connecting passage (64).

14. The air conditioner according to claim 13, wherein the third expansion valve (66) has a smaller capacity than the first expansion valve (40) and the second expansion valve (42).

15. The air conditioner according to claim 13 or 14, wherein:

at a partial heating load, the second compressor (8) operates, the first compressor (2) is in a stopped state, and the third expansion valve (56) is closed; and
at a full heating load, the first compressor (2)

and the second compressor (8) operate, and the third expansion valve (56) is opened.

16. A method using an air conditioner according to any of claims 1 to 15 comprising the steps of:

using a first compressor (2);
using a second compressor (8) connected to the first compressor (2) in parallel by a refrigerant suction line (4) and a refrigerant discharge line (6);
evaporating a refrigerant in a cooling mode, and condensing the refrigerant in a heating mode in a first heat exchanger (10);
condensing the refrigerant in the cooling mode, and evaporating the refrigerant in the heating mode in a second heat exchanger (12);
using a first expansion valve (40) arranged between the first heat exchanger (10) and the second heat exchanger (12);
using a second expansion valve (42) arranged between the first expansion valve (40) and the second heat exchanger (12);
guiding a portion of the refrigerant, which emerges from the first expansion valve (40), to flow to a point between a branching point (22) of the refrigerant suction line (4) and the second compressor (8) after bypassing the second expansion valve (42) and the second heat exchanger (12) by using a bypass device (50) being connected between the branching point (22) of the refrigerant suction line (4) and the second compressor (8); and
preventing the refrigerant, which emerges from the bypass device (50), from flowing to the branching point (22) of the refrigerant suction line (4) by using a one-way valve (60) arranged between the branching point (22) of the refrigerant suction line (4) and a connecting point (58) of the bypass device (50) to the refrigerant suction line (4).

FIG. 1

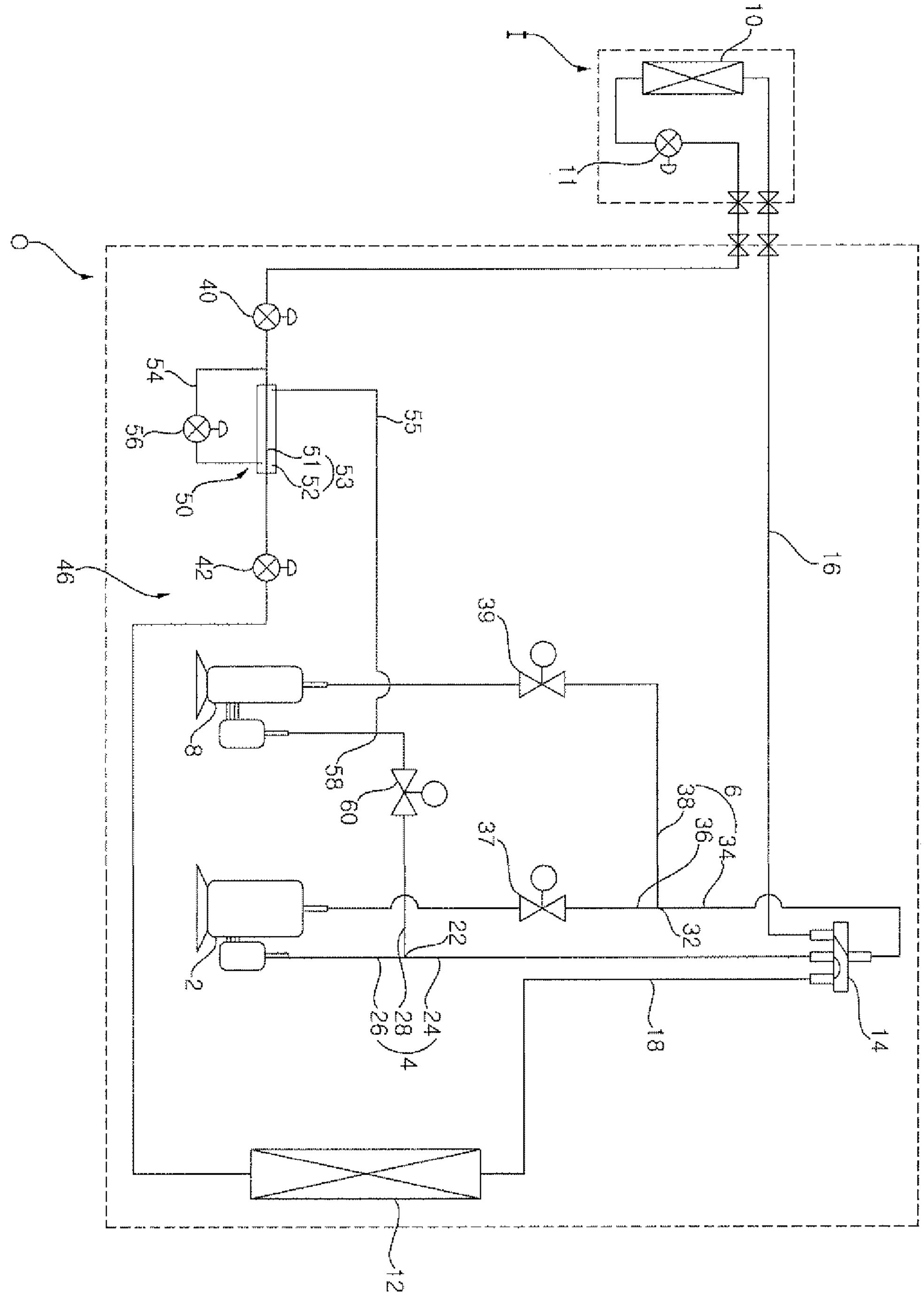
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FIG. 2

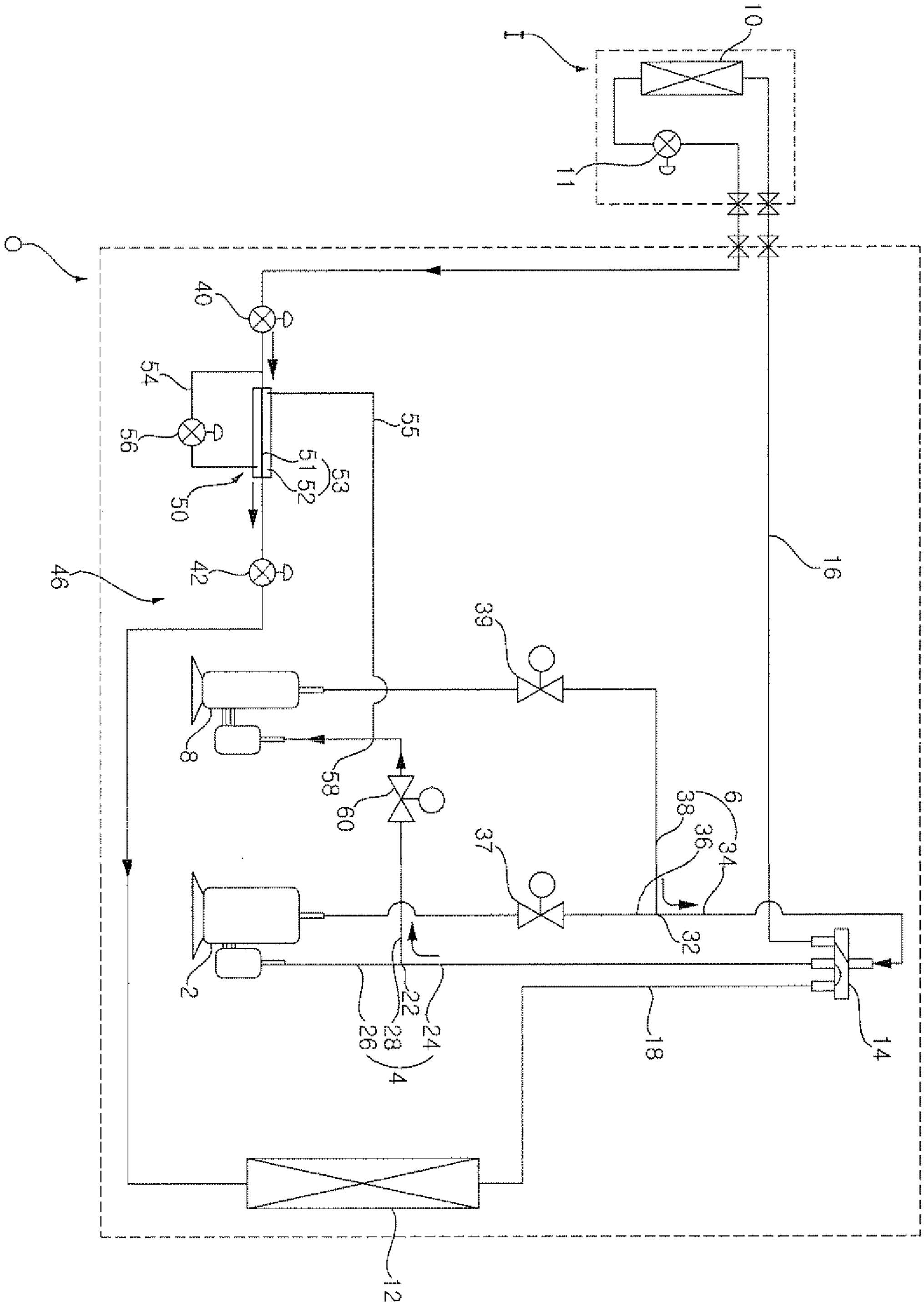
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FIG. 3

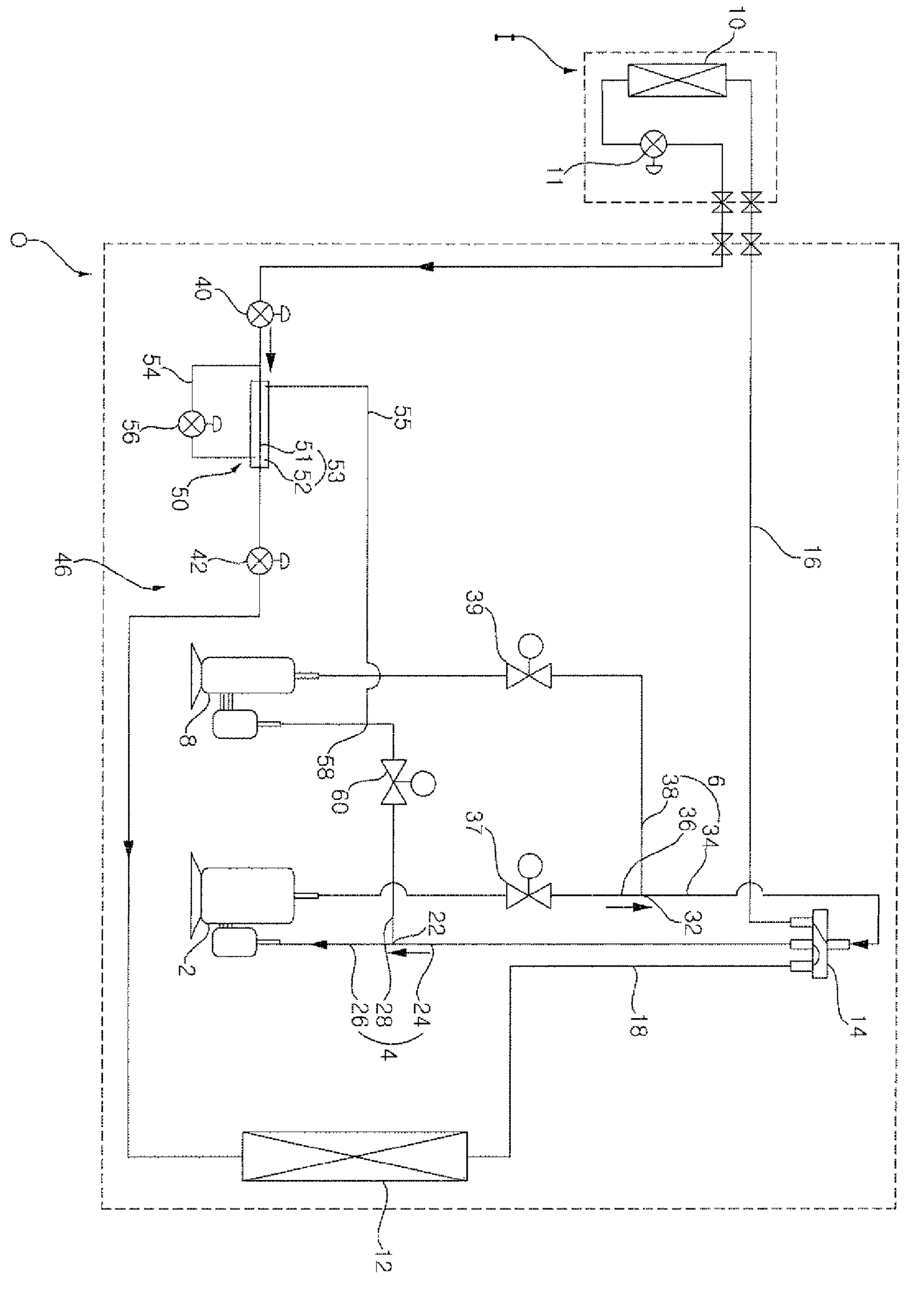
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FIG. 4

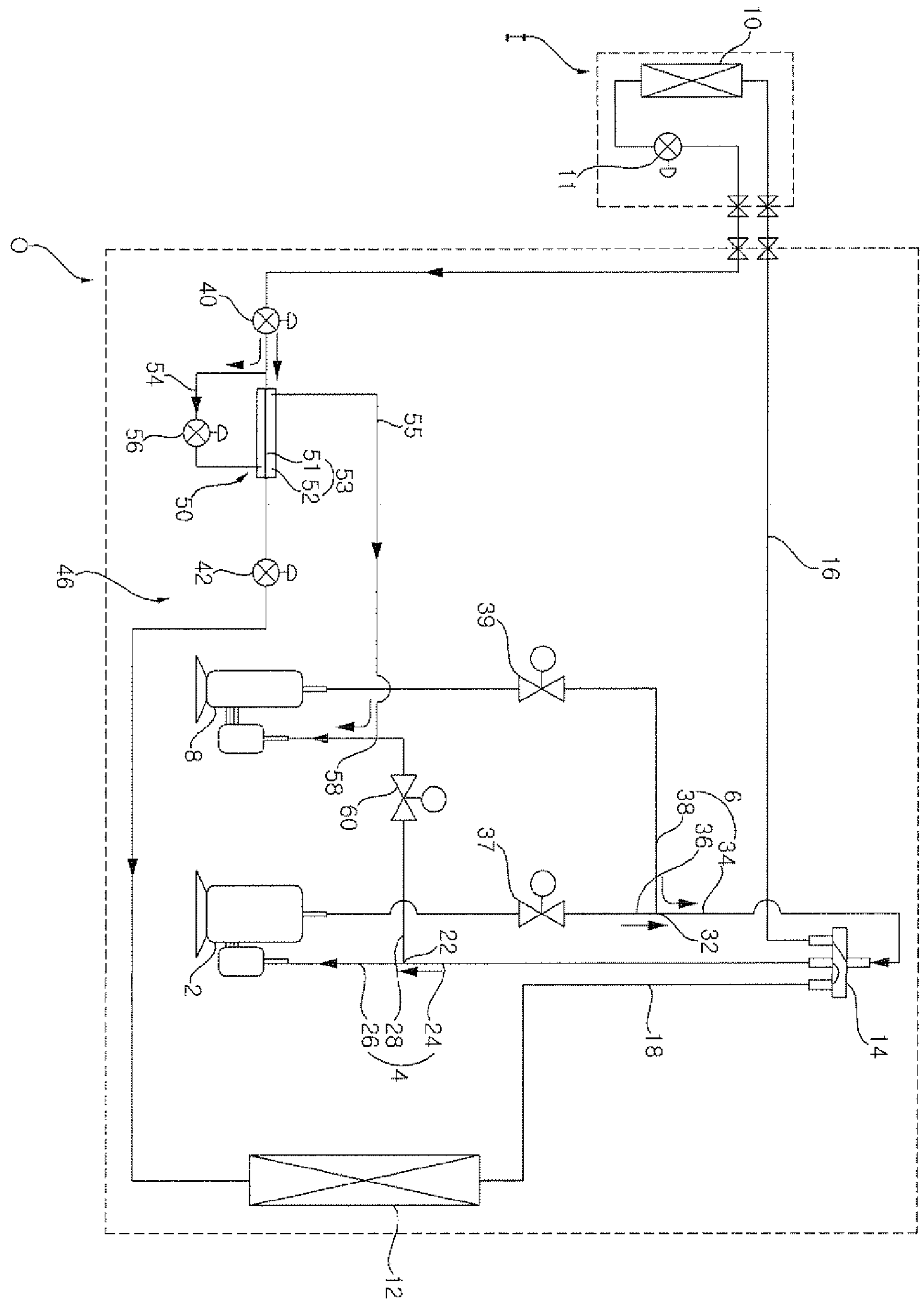
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FIG. 5

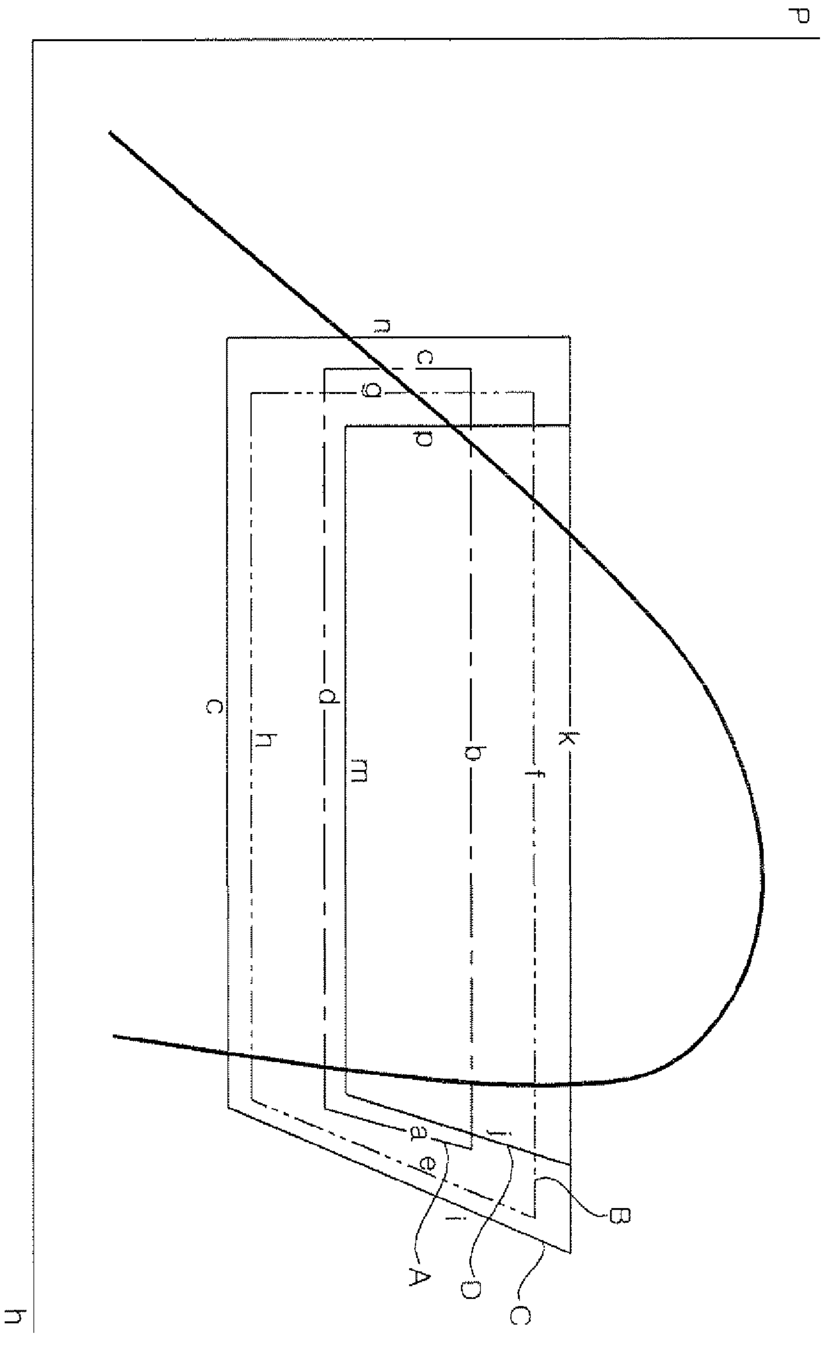

FIG. 6

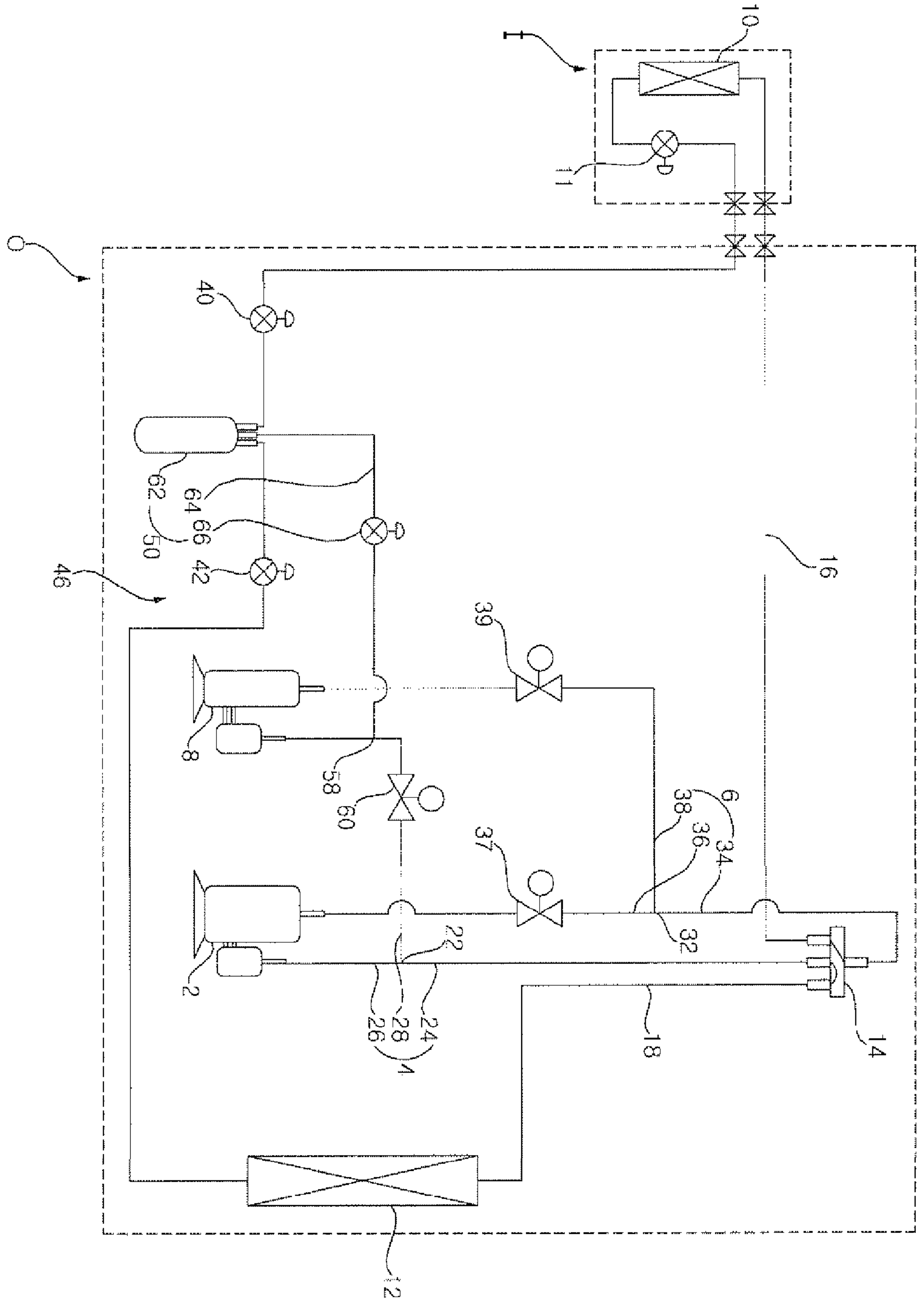
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FIG. 7

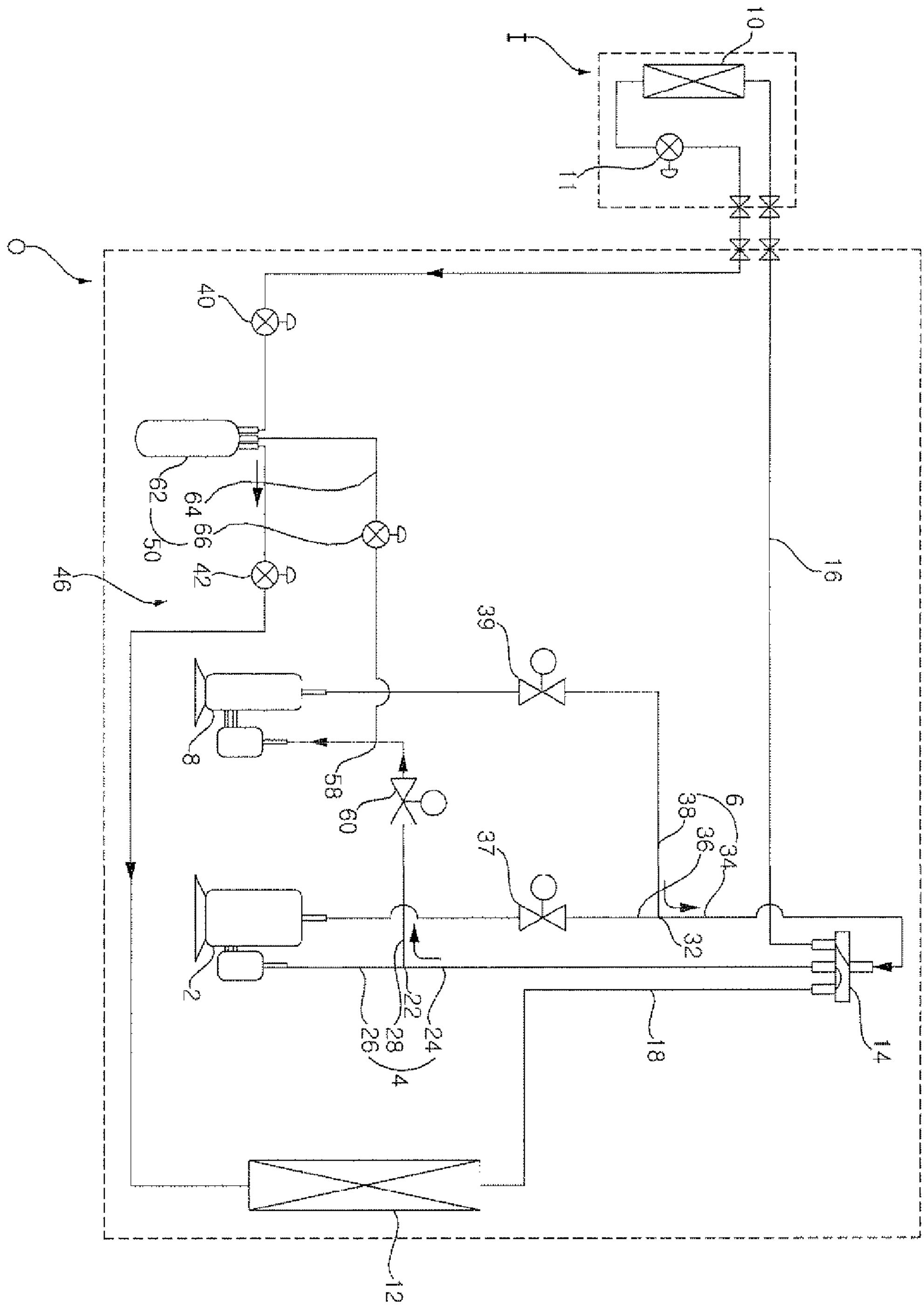
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FIG. 8

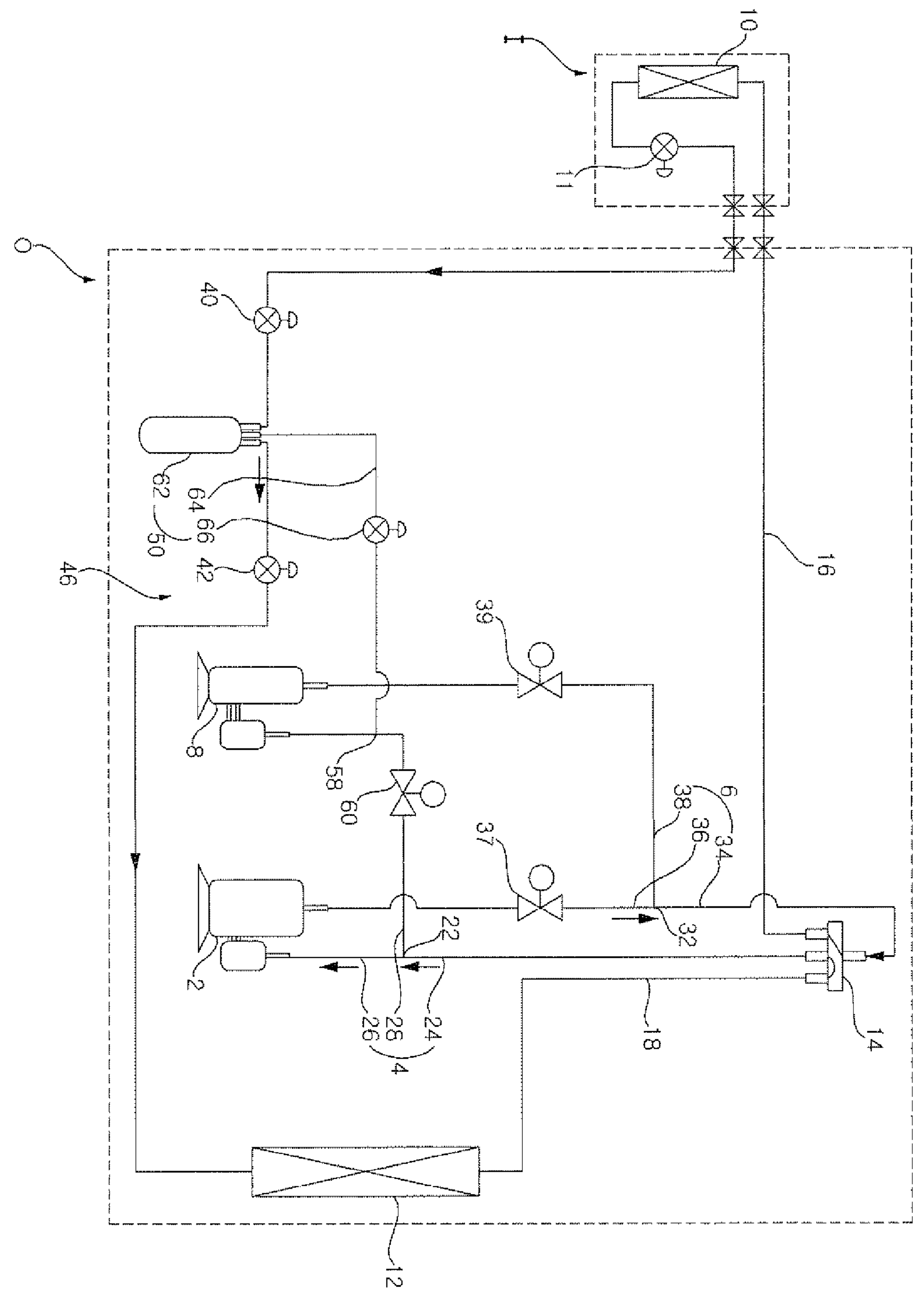
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FIG. 9

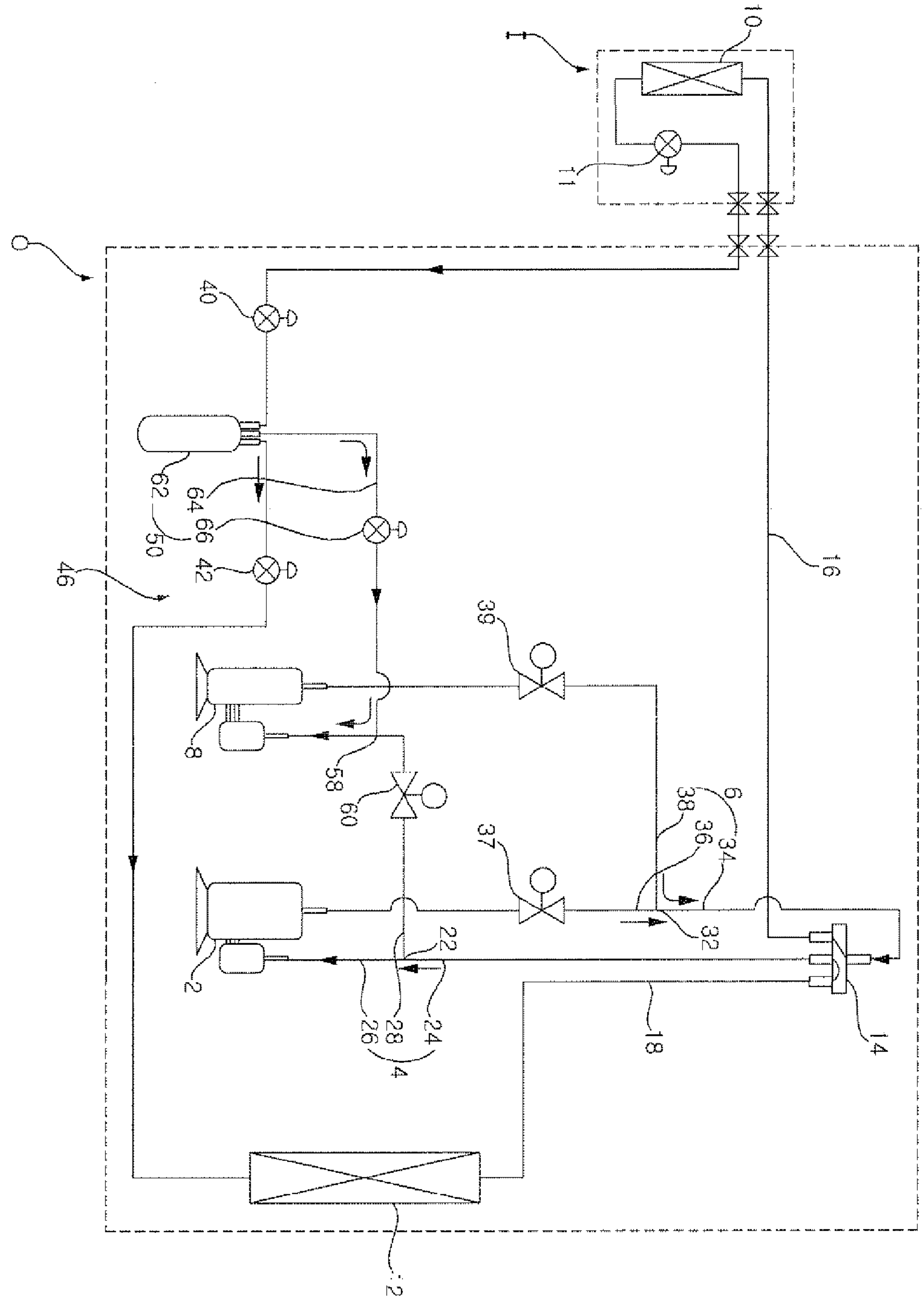
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FIG. 10