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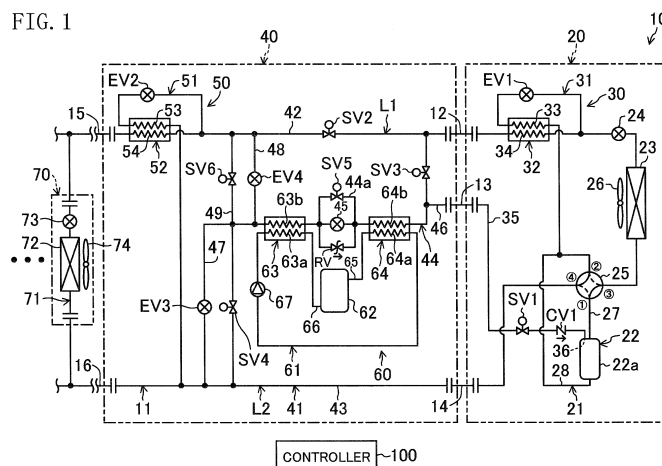
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(54) **REGENERATIVE AIR CONDITIONER**

(57) A refrigerant circuit (11) includes a primary thermal storage channel (44) to which a thermal storage section (60) is connected, and an intermediate suction portion (35) through which the refrigerant having an intermediate pressure between high and low pressures in the refrigerant circuit (11) is taken into a compressor section (22, 80). The refrigerant circuit (11) performs a first utilization heating operation in which part of the refrigerant which has been condensed in an indoor heat exchanger

(72) is diverged into the primary thermal storage channel (44), is evaporated in the thermal storage section (60), and is then taken into the intermediate suction portion (35) of the compressor section (22, 80), and simultaneously, the rest of the refrigerant which has been condensed in the indoor heat exchanger (72) is evaporated in an outdoor heat exchanger (23), and is then taken into a low-pressure suction portion (28, 84) of the compressor section (22, 80).

FIG. 1



Description**TECHNICAL FIELD**

[0001] The present invention relates to a thermal storage air conditioner.

BACKGROUND ART

[0002] Air conditioners which cool and heat a room have been known. Patent document 1 discloses a thermal storage air conditioner using a thermal storage medium. The thermal storage air conditioner has a refrigerant circuit to which a compressor section, an outdoor heat exchanger, and an indoor heat exchanger are connected, and a thermal storage section which exchanges heat between a refrigerant in the refrigerant circuit and the thermal storage medium. For example, FIG. 9 of Patent Document 1 discloses a utilization heating operation which utilizes warm thermal energy stored in the thermal storage medium to heat a room. In this utilization heating operation, the refrigerant that has been compressed by the compressor is condensed by a plurality of indoor heat exchangers, has its pressure reduced by a pressure-reducing valve, and flows through the thermal storage section. In the thermal storage section, the refrigerant absorbs heat from the thermal storage medium and evaporates. The warm thermal energy of the thermal storage medium is given to the refrigerant in this manner.

CITATION LIST**PATENT DOCUMENT**

[0003] Patent Document 1: Japanese Unexamined Patent Publication No. 2007-17089

SUMMARY OF THE INVENTION**TECHNICAL PROBLEM**

[0004] In the utilization heating operation disclosed in FIG. 9 of Patent Document 1, all of the refrigerant condensed in the indoor heat exchanger flows through the thermal storage section. The thermal storage section therefore needs to store a large amount of warm thermal energy in the thermal storage medium to evaporate all the refrigerant.

[0005] In view of the foregoing background, it is therefore an object of the present invention to provide a thermal storage air conditioner capable of performing an energy-efficient utilization heating operation while reducing an amount of warm thermal energy (i.e., an amount of thermal energy stored) given to a refrigerant from a thermal storage medium.

SOLUTION TO THE PROBLEM

[0006] A first aspect of the present invention is directed to a regenerative air conditioner including refrigerant circuit (11) to which a compressor section (22, 80) which compresses a refrigerant, an outdoor heat exchanger (23), and an indoor heat exchanger (72) are connected; and a thermal storage section (60) in which heat is exchanged between the refrigerant in the refrigerant circuit (11) and a thermal storage medium. The refrigerant circuit (11) includes a primary thermal storage channel (44) to which a thermal storage section (60) is connected, and an intermediate suction portion (35) through which the refrigerant having an intermediate pressure between high and low pressures in the refrigerant circuit (11) is taken into a compressor section (22, 80). The refrigerant circuit (11) performs a first utilization heating operation in which part of the refrigerant which has been condensed in the indoor heat exchanger (72) is diverged into the primary thermal storage channel (44), is evaporated in the thermal storage section (60), and is then taken into the intermediate suction portion (35) of the compressor section (22, 80), and simultaneously, a rest of the refrigerant which has been condensed in the indoor heat exchanger (72) is evaporated in the outdoor heat exchanger (23), and then taken into a low-pressure suction portion (28, 84) of the compressor section (22, 80).

[0007] In the first utilization heating operation of the first aspect of the invention, the refrigerant discharged from the compressor section (22, 80) is condensed in the indoor heat exchanger (72). As a result, air is heated by the refrigerant in the indoor heat exchanger (72), and the room is heated. Part of the refrigerant condensed in the indoor heat exchanger (72) flows through the primary thermal storage channel (44), and evaporates in the thermal storage section (60). That is, the warm thermal energy of the thermal storage medium is given to the refrigerant in the thermal storage section (60). The refrigerant to which the heat in the thermal storage medium is given in the thermal storage section (60) is taken into the intermediate suction portion (35) of the compressor section (22, 80). The rest of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the outdoor heat exchanger (23), receives heat from the outdoor air, and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

[0008] In this manner, in the first utilization heating operation, only part of the refrigerant which has been condensed in the indoor heat exchanger (72) flows through the thermal storage section (60), and the rest of the refrigerant flows through the outdoor heat exchanger (23) without flowing through the thermal storage section (60). This configuration reduces the amount of refrigerant flowing through the thermal storage section (60). The amount of thermal energy stored in the thermal storage medium that is necessary to evaporate the refrigerant is accordingly reduced. Further, the refrigerant which has evaporated in the thermal storage section (60) is taken into the

intermediate suction portion (35) of the compressor section (22, 80). The refrigerant which has evaporated in the outdoor heat exchanger (23) is taken into the low-pressure suction portion (28, 84) of the outdoor heat exchanger (23). Thus, in the compressor section (22, 80), the overall workloads required to compress the refrigerant to a high pressure are reduced.

[0009] A second aspect of the present invention is an embodiment of the first aspect. In the second aspect, the refrigerant circuit (11) performs a second utilization heating operation in which all of the refrigerant which has been condensed in the indoor heat exchanger (72) flows into the primary thermal storage channel (44), is evaporated in the thermal storage section (60), and is then taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

[0010] In the refrigerant circuit (11) of the second aspect of the invention, the first utilization heating operation is switched to the second utilization heating operation. For example, suppose that the temperature of the thermal storage medium declines due to the execution of the first utilization heating operation. In such a condition, the second utilization heating operation may be preferred to the first utilization heating operation in some cases.

[0011] For example, suppose that the temperature of the thermal storage medium declines to almost an outside-air temperature. In the first utilization heating operation performed under such a condition, the evaporation temperature (or the evaporating pressure) of the refrigerant also declines in the thermal storage section (60) because the temperature of the thermal storage medium is relatively low. In the first utilization heating operation under such a condition, the difference (MP-LP) between the pressure MP of the refrigerant which has evaporated in the thermal storage section (60) and the pressure LP of the refrigerant which has evaporated in the outdoor heat exchanger (23) is lower than a predetermined value. In the first utilization heating operation under such a condition, the pressure MP of the refrigerant to be taken into the intermediate suction portion (35) is low. Therefore this refrigerant is hard to be taken into the intermediate suction portion (35) (i.e., the portion of the compressor section (22, 80) in the middle of a compression process). Further, under the condition in which the pressure difference (MP-LP) is small, great workloads are required to compress the intermediate-pressure refrigerant. Thus, workloads of the compressor section (22, 80) cannot be reduced sufficiently.

[0012] To address this inconvenience, the present invention allows the second utilization heating operation to be performed under the condition described above. In the second utilization heating operation, all of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the thermal storage section (60), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80). Thus, even if the refrigerant which has evaporated in the thermal storage section (60) has a low pressure MP, this refrigerant

may be taken into the compressor section (22, 80) with reliability.

[0013] A third aspect of the invention is an embodiment of the second aspect. In the third aspect, the refrigerant circuit (11) includes a low-pressure introduction pipe (31) which communicates a liquid line (L1) of the refrigerant circuit (11) with the low-pressure suction portion (28, 84) of the compressor section (22, 80) and has a pressure-reducing valve (EV1), and a first heat exchanger (32) which, in a cooling operation, exchanges heat between the refrigerant, the pressure of which has been reduced by the pressure-reducing valve (EV1) of the low-pressure introduction pipe (31), and the refrigerant flowing through the liquid line (L1). In the refrigerant circuit (11) in the second utilization heating operation, at least part of the refrigerant which has been evaporated in the thermal storage section (60) passes through the fully-opened pressure-reducing valve (EV1) of the low-pressure introduction pipe (31), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

[0014] In the third aspect of the invention, the low-pressure introduction pipe (31) is connected to the refrigerant circuit (11). The low-pressure introduction pipe (31) connects the liquid line (L1) of the refrigerant circuit (11) and the low-pressure suction portion (24, 84) of the compressor section (22, 80). In a cooling operation, heat is exchanged between the refrigerant flowing through the liquid line (L1) and the refrigerant, the pressure of which has been reduced by the pressure-reducing valve (EV1) of the low-pressure introduction pipe (31). As a result, the degree of subcooling of the refrigerant flowing through the liquid line (L1) increases, and the cooling capacity is improved.

[0015] In the second utilization heating operation of the present invention, the low-pressure introduction pipe (31) also serves as a flow channel which introduces the refrigerant evaporated in the thermal storage section (60) to the low-pressure suction portion (28, 84) of the compressor section (22, 80). That is, all of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the thermal storage section (60) in the second utilization heating operation. The evaporated low-pressure refrigerant flows through the low-pressure introduction pipe (31), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

[0016] A fourth aspect of the invention is an embodiment of the third aspect. In the fourth aspect, In the refrigerant circuit (11) in the second utilization heating operation, part of the refrigerant which has been evaporated in the thermal storage section (60) passes through the fully-opened pressure-reducing valve (EV1) of the low-pressure introduction pipe (31), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80), and simultaneously, a rest of the refrigerant which has been evaporated in the thermal storage section (60) passes through the outdoor heat exchanger (23), and is taken into the low-pressure suction portion

(28, 84) of the compressor (22).

[0017] In the fourth aspect of the invention, the low-pressure introduction pipe (31) and the outdoor heat exchanger (23) also serve as a flow channel which introduces the refrigerant which has evaporated in the thermal storage section (60) into the low-pressure suction portion (28, 84) of the compressor section (22, 80). That is, all of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the thermal storage section (60) in the second utilization heating operation. Part of the evaporated low-pressure refrigerant flows through the low-pressure introduction pipe (31), and the rest of the refrigerant flows through the outdoor heat exchanger (23). These refrigerants are taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

[0018] A fifth aspect of the invention is an embodiment of the fourth aspect. In the fifth aspect, the regenerative air conditioner includes an outdoor fan (26) which transfers air passing through the outdoor heat exchanger (23) and which is stopped in the second utilization heating operation.

[0019] In the fifth aspect of the invention, the outdoor fan (26) is stopped in the second utilization heating operation. Thus, even if the refrigerant which has evaporated in the thermal storage section (60) flows through the outdoor heat exchanger (23), the heat exchange between the refrigerant and the outdoor air may not be accelerated. That is, heat loss of the refrigerant dissipated to the air may be reduced.

[0020] A sixth aspect of the invention is an embodiment of any one of the first to fifth aspects. In the sixth aspect, the compressor section (22, 80) is configured as a single-stage compressor (22), and the intermediate suction portion (35) communicates with a compression chamber of the single-stage compressor (22) in the middle of a compression process.

[0021] In the sixth aspect of the invention, the compressor section (22, 80) is configured as a single-stage compressor section (22). In the first utilization heating operation, the intermediate-pressure refrigerant which has evaporated in the thermal storage section (60) is taken into the compression chamber of the compressor (22) in the middle of the compression process.

[0022] A seventh aspect of the invention is an embodiment of the sixth aspect. In the seventh aspect, a check valve (CV1) is connected to the intermediate suction portion (35), the check valve (CV1) preventing the refrigerant from flowing in a direction from the compressor (22) toward the thermal storage section (60) in the first utilization heating operation.

[0023] In the seventh aspect of the invention, the intermediate suction portion (35) is provided with the check valve (CV1). In the first utilization heating operation, part of the refrigerant which has evaporated in the thermal storage section (60) passes through the check valve (CV1), and is taken into the compressor (22). That is, the check valve (CV1) in the first utilization heating operation

allows the refrigerant to flow in the direction from the thermal storage section (60) to the compressor (22). On the other hand, the check valve (CV1) in the first utilization heating operation prevents the refrigerant from flowing in the direction from the compressor (22) to the thermal storage section (60).

[0024] In the single-stage compressor (22), the intermediate-pressure refrigerant is introduced to the compression chamber in the middle of the compression process through the intermediate suction portion (35). However, as described above, when the pressure MP of the refrigerant which has evaporated in the thermal storage section (60) is low, the pressure MP may be lower than the internal pressure of the compression chamber in the middle of the compression process. In such a case, the refrigerant in the compression chamber in the middle of the compression process may flow back to the primary thermal storage channel (44) from the intermediate suction portion (35). In the present invention, such a back-flow does not occur since the intermediate suction portion (35) is provided with the check valve (CV1).

[0025] An eighth aspect of the invention is an embodiment of the seventh aspect. In the eighth aspect, the intermediate suction pipe (35) includes an inner pipe portion (36) located inside a casing (22a) of the compressor (22), and the check valve (CV1) is located at the inner pipe portion (36).

[0026] In the eighth aspect of the invention, the inner pipe portion (36) of the intermediate suction portion (35) is located inside the casing (22a) of the compressor (22). The inner pipe portion (36) is provided with the check valve (CV1). This configuration may achieve a shorter channel length (channel capacity) from the check valve (CV1) to the compression chamber of the compressor (22) in the middle of the compression process, thereby making it possible to reduce a so-called dead volume that does not contribute to the compression of the refrigerant.

[0027] A ninth aspect of the invention is an embodiment of any one of the first to fifth aspects. In the ninth aspect, the compressor section (22, 80) is configured as a compressor section (80) of a two-stage compression type, the compressor section (80) having a low-stage compressor (81) which compresses a low-pressure refrigerant, and a high-stage compressor (82) which further compresses the refrigerant which has been compressed in the low-stage compressor (81) in the first utilization heating operation, and the intermediate suction portion (35) communicates with a suction pipe (86) of the high-stage compressor (82).

[0028] In the ninth aspect of the invention, the compressor section (22, 80) is configured as a compressor section (80) of a two-stage compression type. That is, in the first utilization heating operation, the low-pressure refrigerant is compressed to an intermediate pressure by the low-stage compressor (81). This refrigerant having an intermediate-pressure is further compressed to a high pressure in the high-stage compressor (82). In the first

utilization heating operation, the intermediate-pressure refrigerant which has evaporated in the thermal storage section (60) is taken into the high-stage compressor (82) through the intermediate suction portion (35). This configuration reduces the workload of compression by the low-stage compressor (81).

[0029] A tenth aspect of the invention is an embodiment of any one of the first to ninth aspects. In the tenth aspect, the refrigerant circuit (11) includes an intermediate introduction pipe (91) which communicates a liquid line (L1) of the refrigerant circuit (11) with the intermediate suction portion (35) and has a pressure-reducing valve (EV5), and a second heat exchanger (92) which exchanges heat between the refrigerant flowing through the liquid line (L1) after being condensed in the indoor heat exchanger (72) and the refrigerant having a pressure reduced by the pressure-reducing valve (EV5) of the intermediate introduction pipe (91). In the refrigerant circuit (11) in the first utilization heating operation, the refrigerant which is controlled to be in a wet-vapor state by the pressure-reducing valve (EV5) of the intermediate introduction pipe (91) is mixed with the refrigerant which has been evaporated in the thermal storage section (60), and is taken into the intermediate suction portion (35).

[0030] In the tenth aspect of the invention, the intermediate introduction pipe (91) is connected to the refrigerant circuit (11). In the first utilization heating operation, part of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the thermal storage section (60), and simultaneously, the rest of the refrigerant which has been condensed in the indoor heat exchanger (72) flows through the liquid line (L1). The refrigerant flowing through the liquid line (L1) flows through the intermediate introduction pipe (91), and the pressure thereof is reduced by the pressure-reducing valve (EV5). In the second heat exchanger (92), heat is exchanged between the pressure-reduced refrigerant and the refrigerant in the liquid line (L1). Here, the degree of opening of the pressure-reducing valve (EV5) is adjusted such that the refrigerant flowing out of the intermediate introduction pipe (91) is in a wet-vapor state. Thus, if the refrigerant which has flowed out of the intermediate introduction pipe (91) and the refrigerant which has evaporated in the thermal storage section (60) are mixed together, the refrigerant to be taken into the intermediate suction portion (35) has a smaller degree of superheat. As a result, the compression efficiency of the high-stage compressor (82) is improved.

[0031] An eleventh aspect of the invention is an embodiment of any one of the first to tenth aspects. In the eleventh aspect, The control section (60) includes a thermal storage circuit (61) to which a thermal storage tank (62) and a thermal storage heat exchanger (63) are connected and in which the thermal storage medium circulates, the thermal storage tank (62) accumulating the thermal storage medium, and the thermal storage heat exchanger (63) exchanging heat between the refrigerant in the refrigerant circuit (11) and the thermal storage me-

dium.

[0032] In the eleventh aspect of the invention, the thermal storage section (60) includes the thermal storage circuit (61) in which the thermal storage medium circulates. For example, warm thermal energy is stored in the thermal storage medium when heat is exchanged in the thermal storage heat exchanger (63) between the refrigerant having a relatively high temperature and the thermal storage medium. The thermal storage medium in which the warm thermal energy is stored in this manner is accumulated in the thermal storage tank (62). In the first utilization heating operation, heat of the thermal storage medium stored as the warm thermal energy is given to part of the refrigerant which has been condensed in the indoor heat exchanger (72). In the first utilization heating operation, not all of the refrigerant which has been condensed in the indoor heat exchanger (72) flows through the thermal storage heat exchanger (63). Thus, the amount of warm thermal energy that should be stored in the thermal storage medium may be reduced.

ADVANTAGES OF THE INVENTION

[0033] According to the first aspect of the invention, only part of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the thermal storage section (60) in the first utilization heating operation. Thus, the amount of warm thermal energy that should be stored in the thermal storage section (60) may be reduced. Further, in the first utilization heating operation, the refrigerant which has evaporated in the thermal storage section (60) is taken into the intermediate suction portion (35) of the compressor section (22, 80). Thus, the compression workloads of the compressor section (22, 80) may be reduced, and the energy efficiency of the thermal storage air conditioner may be improved. According to the present invention, the compression efficiency of the compressor section (22, 80) may be improved because the degree of superheat of the refrigerant taken into the compressor section (22, 80) does not become excessively large.

[0034] According to the second aspect of the invention, a heating operation can be performed while utilizing the warm thermal energy of the thermal storage medium of the thermal storage section (60), even under a condition in which the difference (MP-LP) between the evaporating pressure MP of the refrigerant in the thermal storage section (60) and the evaporating pressure LP of the refrigerant in the outdoor heat exchanger (23) is relatively small.

[0035] According to the third aspect of the invention, the degree of subcooling of the refrigerant may be increased using the first heat exchanger (32) in a cooling operation. Thus, the energy efficiency in the cooling operation may be improved. The low-pressure introduction pipe (31) serves as a flow channel for subcooling during the cooling operation, and as a flow channel for taking the refrigerant which has evaporated in the thermal stor-

age section (60) during the second utilization heating operation into the low-pressure suction portion (28, 84) of the compressor section (22, 80). Thus, the number of pipes can be reduced. If all the refrigerant which has evaporated in the thermal storage section (60) is transferred to the low-pressure suction portion (28, 84) of the compressor section (22, 80) via the outdoor heat exchanger (23) in the second utilization heating operation, the refrigerant flowing through the outdoor heat exchanger (23) dissipates more heat to the outdoor air, which increases the heat loss in the second utilization heating operation. On the other hand, according to the present invention, the refrigerant which has evaporated in the thermal storage section (60) bypasses the outdoor heat exchanger (23) before it is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80). Thus, such an increase in the heat loss may be prevented.

[0036] According to the fourth aspect of the invention, the refrigerant which has evaporated in the thermal storage section (60) flows to both of the low-pressure introduction pipe (31) and the outdoor heat exchanger (23) before it is transferred to the low-pressure suction portion (28, 84) in the second utilization heating operation. Thus, the pressure loss of the refrigerant may be reduced, and therefore the power to actuate the compressor section (22, 80) may be reduced, compared with a case in which the refrigerant flows into only one of the introduction pipe (31) and the outdoor heat exchanger (23).

[0037] According to the fifth aspect of the invention, the outdoor fan (26) is stopped in the second utilization heating operation. Thus, the heat loss of the refrigerant in the outdoor heat exchanger (23) may be reduced reliably.

[0038] According to the sixth aspect of the invention, the advantages in the first aspect of the invention may be obtained in the thermal storage air conditioner using a single-stage compressor (22). In particular, according to the seventh aspect of the invention, the check valve (CV1) may reliably prevent the refrigerant from flowing back in the direction from the intermediate suction portion (35) of the compressor (22) to the thermal storage section (60) in the first utilization heating operation. Thus, the warm thermal energy of the thermal storage medium of the thermal storage section (60) may be reliably utilized to heat the room. Moreover, according to the eighth aspect of the invention, a dead volume of the compression chamber of the compressor (22) may be minimized, thereby making it possible to prevent decline in the compression efficiency.

[0039] According to the ninth aspect of the invention, the advantages in the first aspect of the invention may be obtained in the thermal storage air conditioner using a two-stage compressor section (80).

[0040] According to the tenth aspect of the invention, the refrigerant which has evaporated in the thermal storage section (60) and the refrigerant which has been turned into a wet-vapor state in the second heat exchanger

(92) are mixed together. Thus, the degree of superheat of the refrigerant taken into the intermediate suction portion (35) may be reduced, and the compression efficiency of the high-stage compressor (82) may be improved.

[0041] According to the eleventh aspect of the invention, the amount of warm thermal energy (i.e., the amount of thermal energy stored) in the thermal storage medium necessary to heat the refrigerant may be reduced. Thus, the thermal storage tank (62) may be downsized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042]

[FIG. 1] FIG. 1 is a piping diagram generally illustrating a configuration of a thermal storage air conditioner according to a first embodiment.

[FIG. 2] FIG. 2 is a view corresponding to FIG. 1 illustrating the behavior of a simple cooling operation.

[FIG. 3] FIG. 3 is a view corresponding to FIG. 1 illustrating the behavior of a cold thermal energy storage operation.

[FIG. 4] FIG. 4 is a view corresponding to FIG. 1 illustrating the behavior of a utilization cooling operation.

[FIG. 5] FIG. 5 is a view corresponding to FIG. 1 illustrating the behavior of a cooling and cold thermal energy storage operation.

[FIG. 6] FIG. 6 is a view corresponding to FIG. 1 illustrating the behavior of a simple heating operation.

[FIG. 7] FIG. 7 is a view corresponding to FIG. 1 illustrating the behavior of a warm thermal energy storage operation.

[FIG. 8] FIG. 8 is a view corresponding to FIG. 1 illustrating a first utilization heating operation (or a utilization heating operation (1)).

[FIG. 9] FIG. 9 is a view corresponding to FIG. 1 illustrating a heating and warm thermal energy storage operation.

[FIG. 10] FIG. 10 is a view corresponding to FIG. 1 illustrating a second utilization heating operation (or a utilization heating operation (2)) according to the first embodiment.

[FIG. 11] FIG. 11 is a view corresponding to FIG. 1 illustrating a second utilization heating operation (or a utilization heating operation (3)) according to the first embodiment.

[FIG. 12] FIG. 12 is a view corresponding to FIG. 1 illustrating a second utilization heating operation (or a utilization heating operation (4)) according to the first embodiment.

[FIG. 13] FIG. 13 is a piping diagram generally illustrating a configuration of a thermal storage air conditioner according to a second embodiment.

[FIG. 14] FIG. 14 is a piping diagram generally illustrating a configuration of an air conditioner installed

already and prior to adding a thermal storage unit thereto.

[FIG. 15] FIG. 15 is a view corresponding to FIG. 13 illustrating a first utilization heating operation (or a utilization heating operation (1)) according to the second embodiment.

[FIG. 16] FIG. 16 is a view corresponding to FIG. 13 illustrating a second utilization heating operation (or a utilization heating operation (2)) according to the second embodiment.

[FIG. 17] FIG. 17 is a piping diagram generally illustrating a configuration of a thermal storage air conditioner according to a variation of the second embodiment, illustrating a first utilization heating operation (or a utilization heating operation (1)).

DESCRIPTION OF EMBODIMENTS

[0043] Embodiments of the present invention will be described in detail below, with reference to the drawings. Note that the following description of the embodiments is merely beneficial examples in nature, and is not intended to limit the scope, application, or uses of the present disclosure.

(First Embodiment of The Invention)

[0044] A thermal storage air conditioner (10) according to a first embodiment of the present invention selectively performs cooling and heating of a room. The thermal storage air conditioner (10) stores cold thermal energy of a refrigerant in a thermal storage medium, and utilizes this cold thermal energy for cooling the room. The thermal storage air conditioner (10) stores warm thermal energy of the refrigerant in the thermal storage medium, and utilizes this warm thermal energy for heating the room.

<General Configuration>

[0045] As illustrated in FIG. 1, the thermal storage air conditioner (10) is comprised of an outdoor unit (20), a thermal storage unit (40), and a plurality of indoor units (70). The outdoor unit (20) and the thermal storage unit (40) are installed outside of a room. The plurality of indoor units (70) are installed in the room. For the sake of convenience, only one indoor unit (70) is illustrated in FIG. 1.

[0046] The outdoor unit (20) includes an outdoor circuit (21). The thermal storage unit (40) includes an intermediate circuit (41). The indoor unit (71) includes an indoor circuit (71). In the thermal storage air conditioner (10), the outdoor circuit (21) and the intermediate circuit (41) are connected to each other via three communication pipes (12, 13, 14), and the intermediate circuit (41) and the plurality of indoor circuits (71) are connected to each other via two communication pipes (15, 16). Thus, the thermal storage air conditioner (10) forms a refrigerant circuit (11) in which a refrigerant filling the thermal storage air conditioner (10) circulates to perform a refrigeration

cycle. The thermal storage air conditioner (10) has a controller (100) (an operation control section) which controls various devices, which will be described later.

5 <Outdoor Unit>

[0047] The outdoor unit (20) includes an outdoor circuit (21) which forms part of the refrigerant circuit (11). A compressor (22), an outdoor heat exchanger (23), an outdoor expansion valve (24), and a four-way switching valve (25) are connected to the outdoor circuit (21). A first subcooling circuit (30) and an intermediate suction pipe (35) are connected to the outdoor circuit (21).

15 [Compressor]

[0048] The compressor (22) of the present embodiment is a single-stage compressor, and forms a compression section which compresses the refrigerant and discharges the compressed refrigerant. The compressor (22) has a casing (22a), in which a motor and a compression mechanism (not shown) are housed. The compression mechanism of the first embodiment is configured as a scroll compression mechanism. However, the compression mechanism may be any one of various types such as oscillating piston, rolling piston, screw, and turbo compressors. The compression mechanism includes a compression chamber between a spiral-shaped fixed scroll and a movable scroll. The refrigerant is compressed as the capacity of the compression chamber gradually decreases. The motor of the compressor (22) has a variable operating frequency which is varied by an inverter section. That is, the compressor (22) is an inverter compressor, the rotational frequency (i.e., the capacity) of which is variable.

[Outdoor Heat Exchanger]

[0049] The outdoor heat exchanger (23) is configured as a cross-fin-and-tube heat exchanger, for example. An outdoor fan (26) is provided adjacent to the outdoor heat exchanger (23). The outdoor heat exchanger (23) exchanges heat between the air transferred by the outdoor fan (26) and the refrigerant flowing through the outdoor heat exchanger (23).

[Outdoor Expansion Valve]

[0050] The outdoor expansion valve (24) is arranged between a liquid-side end of the outdoor heat exchanger (23) and a connection end of the communication pipe (12). The outdoor expansion valve (24) is configured, for example, as an electronic expansion valve, and adjusts the flow rate of the refrigerant by changing the degree of opening of the valve.

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[Four-Way Switching Valve]

[0051] The four-way switching valve (25) has first to fourth ports. The first port of the four-way switching valve (25) is connected to the discharge pipe (27) of the compressor (22). The second port of the four-way switching valve (25) is connected to a suction pipe (28) (a low-pressure suction portion) of the compressor (22). The third port of the four-way switching valve (25) is connected to a gas-side end of the outdoor heat exchanger (23). The fourth port of the four-way switching valve (25) is connected to a connection end of the communication pipe (14).

[0052] The four-way switching valve (25) is configured to switch between a state in which the first port and the third port communicate with each other and the second port and the fourth port communicate with each other (i.e., a first state indicated by solid lines in FIG. 1) and a state in which the first port and the fourth port communicate with each other and the second port and the third port communicate with each other (i.e., a second state indicated by broken lines in FIG. 1).

[First Subcooling Circuit]

[0053] The first subcooling circuit (30) includes a first introduction pipe (31) and a first subcooling heat exchanger (32). One end of the first introduction pipe (31) is connected between the outdoor expansion valve (24) and the connection end of the communication pipe (12). The other end of the first introduction pipe (31) is connected to the suction pipe (28) of the compressor (22). In other words, the first introduction pipe (31) forms a low-pressure introduction pipe connecting a liquid line (L1) and the suction pipe (28) on the low-pressure side of the compressor (22). Here, the liquid line (L1) is a channel extending between the liquid-side end of the outdoor heat exchanger (23) and a liquid-side end of the indoor heat exchanger (72). A first pressure-reducing valve (EV1) and a first heat transfer channel (33) are connected to the first introduction pipe (31) so as to be arranged sequentially in a direction from one end to the other end of the first introduction pipe (31). The first pressure-reducing valve (EV1) is configured, for example, as an electronic expansion valve, and adjusts the degree of subcooling of the refrigerant at the exit of the second heat transfer channel (34) by changing the degree of opening of the valve. The first subcooling heat exchanger (32) forms a first heat exchanger which exchanges heat between the refrigerant flowing through the second heat transfer channel (34) and the refrigerant flowing through the first heat transfer channel (33). The second heat transfer channel (34) is provided on the liquid line (L1) of the refrigerant circuit (11) between the outdoor expansion valve (24) and the connection end of the communication pipe (12).

[Intermediate Suction Pipe]

[0054] The intermediate suction pipe (35) forms an intermediate suction portion which introduces a refrigerant with an intermediate pressure to the compression chamber of the compressor (22) in the middle of a compression process. The starting end of the intermediate suction pipe (35) is connected to the connection end of the communication pipe (13), and the terminal end of the intermediate suction pipe (35) is connected to the compression chamber of the compression mechanism of the compressor (22). The intermediate suction pipe (35) includes an inner pipe portion (36) located inside the casing (22a) of the compressor (22). The internal pressure of the intermediate suction pipe (35) basically corresponds to an intermediate pressure between the high and low pressures of the refrigerant circuit (11). A first solenoid valve (SV1) and a check valve (CV1) are connected to the intermediate suction pipe (35) so as to be arranged sequentially from the upstream to downstream side. The first solenoid valve (SV1) is an open/close valve for opening and closing the channel. The check valve (CV1) allows the refrigerant to flow in a direction (the arrow direction in FIG. 1) from a primary thermal storage channel (44) (which will be described in detail later) toward the compressor (22), and prohibits the refrigerant from flowing in a direction from the compressor (22) toward the primary thermal storage channel (44).

<Thermal Storage Unit>

[0055] The thermal storage unit (40) forms a junction unit which intervenes between the outdoor unit (20) and the indoor unit (70). The thermal storage unit (40) includes an intermediate circuit (41) which forms part of the refrigerant circuit (11). A primary liquid pipe (42), a primary gas pipe (43), and the primary thermal storage channel (44) are connected to the intermediate circuit (41). A second subcooling circuit (50) is connected to the intermediate circuit (41). The thermal storage unit (40) includes a thermal storage device (60).

[Primary Liquid Pipe]

[0056] The primary liquid pipe (42) forms part of the liquid line (L1). The primary liquid pipe (42) connects a connection end of the communication pipe (12) and a connection end of the communication pipe (15). A second solenoid valve (SV2) is connected to the primary liquid pipe (42). The second solenoid valve (SV2) is an open/close valve for opening and closing the channel.

[Primary Gas Pipe]

[0057] The primary gas pipe (43) forms part of a gas line (L2). Here, the gas line (L2) is a channel extending between the fourth port of the four-way switching valve (25) and a gas-side end of the indoor heat exchanger

(72). The primary gas pipe (43) connects a connection end of the communication pipe (14) and a connection end of the communication pipe (16).

[Primary Thermal Storage Channel]

[0058] The primary thermal storage channel (44) is connected between the primary liquid pipe (42) and the primary gas pipe (43). One end of the primary thermal storage channel (44) is connected between the connection end of the communication pipe (12) and the second solenoid valve (SV2). A third solenoid valve (SV3), a pre-heating-side refrigerant channel (64b), a thermal storage expansion valve (45), a thermal storage-side refrigerant channel (63b), and a fourth solenoid valve (SV4) are connected to the primary thermal storage channel (44) so as to be arranged sequentially in a direction from the primary liquid pipe (42) to the primary gas pipe (43). The third solenoid valve (SV3) and the fourth solenoid valve (SV4) are open/close valves for opening and closing the channels. The thermal storage expansion valve (45) is configured, for example, as an electronic expansion valve, and adjusts the pressure of the refrigerant by changing the degree of opening of the valve.

[0059] A first bypass pipe (44a) which bypasses the thermal storage expansion valve (45) is connected to the primary thermal storage channel (44). A fifth solenoid valve (SV5) is connected to the first bypass pipe (44a) in parallel with the thermal storage expansion valve (45). The fifth solenoid valve (SV5) is an open/close valve for opening and closing the channel. A pressure release valve (RV) is connected to the primary thermal storage channel (44) in parallel with the thermal storage expansion valve (45).

[Second Subcooling Circuit]

[0060] The second subcooling circuit (50) includes a second introduction pipe (51) and a second subcooling heat exchanger (52). One end of the second introduction pipe (51) is connected between the second solenoid valve (SV2) and a connection end of the communication pipe (15). The other end of the second introduction pipe (51) is connected to the primary gas pipe (43). The second introduction pipe (51) is connected to the primary gas pipe (43) between the junction of the primary thermal storage channel (44) with the primary gas pipe (43) and the connection end of the communication pipe (16). A second pressure-reducing valve (EV2) and a third heat transfer channel (53) are connected to the second introduction pipe (51) so as to be arranged sequentially in a direction from one end to the other end of the second introduction pipe (51). The second pressure-reducing valve (EV2) is configured, for example, as an electronic expansion valve, and adjusts the degree of subcooling of the refrigerant at the exit of the fourth heat transfer channel (54) by changing the degree of opening of the valve. The second subcooling heat exchanger (52) ex-

changes heat between the refrigerant flowing through the fourth heat transfer channel (54) and the refrigerant flowing through the third heat transfer channel (53). The fourth heat transfer channel (54) is provided on the primary liquid pipe (42) between the second solenoid valve (SV2) and the connection end of the communication pipe (15). The second subcooling circuit (50) forms a subcooler which prevents the refrigerant flowing through the communication pipe (15) from vaporizing and being flushed in a utilization and cooling operation and a utilization and cold thermal energy storage operation, which will be described in detail later.

[Other Pipes]

[0061] An intermediate junction pipe (46), a first branch pipe (47), a second branch pipe (48), and a third branch pipe (49) are connected to the intermediate circuit (41). One end of the intermediate junction pipe (46) is connected to a portion of the primary thermal storage channel (44) between the third solenoid valve (SV3) and the pre-heating-side refrigerant channel (64b). The other end of the intermediate junction pipe (46) is connected to the intermediate suction pipe (35) via the communication pipe (13). One end of the first branch pipe (47) is connected to a portion of the primary thermal storage channel (44) between the thermal storage-side refrigerant channel (63b) and the fourth solenoid valve (SV4).

[0062] The other end of the first branch pipe (47) is connected to the primary gas pipe (43) between the junction of the primary thermal storage channel (44) with the primary gas pipe (43) and the junction of the second introduction pipe (51) with the primary gas pipe (43). The third pressure-reducing valve (EV3) is connected to the first branch pipe (47). The third pressure-reducing valve (EV3) is configured, for example, as an electronic expansion valve, and adjusts the pressure of the refrigerant by changing the degree of opening of the valve. The degree of opening of the third pressure-reducing valve (EV3) is adjusted to prevent the pressure of the thermal storage heat exchanger (63) from becoming excessively low due to a difference between an evaporating pressure in the indoor heat exchanger (72) and a pressure in the gas pipe (41) caused by a pressure loss of the communication pipe (16) and/or a head difference depending on installation conditions of the indoor unit (70) and the outdoor unit (20).

[0063] The second branch pipe (48) and the third branch pipe (49) are connected to the primary liquid pipe (42) and the primary thermal storage channel (44) in parallel with each other. One end of the second branch pipe (48) and one end of the third branch pipe (49) are connected to portions of the primary thermal storage channel (44) between the thermal storage-side refrigerant channel (63b) and the fourth solenoid valve (SV4). The other end of the second branch pipe (48) and the other end of the third branch pipe (49) are connected to portions of the primary liquid pipe (42) between the second solenoid

valve (SV2) and the junction of the second introduction pipe (51) with the primary liquid pipe (42). The fourth pressure-reducing valve (EV4) is connected to the second branch pipe (48). The fourth pressure-reducing valve (EV4) is configured, for example, as an electronic expansion valve, and adjusts the pressure of the refrigerant by changing the degree of opening of the valve. A sixth solenoid valve (SV6) is connected to the third branch pipe (49). The sixth solenoid valve (SV6) is an open/close valve for opening and closing the channel.

[Thermal Storage Device]

[0064] The thermal storage device (60) forms a thermal storage section in which heat is exchanged between the refrigerant of the refrigerant circuit (11) and the thermal storage medium. The thermal storage device (60) has a thermal storage circuit (61) and a thermal storage tank (62) connected to the thermal storage circuit (61). The thermal storage device (60) has the thermal storage heat exchanger (63) and the preheating heat exchanger (64).

[0065] The thermal storage circuit (61) is a closed circuit in which the thermal storage medium filling the thermal storage circuit (61) circulates. The thermal storage tank (62) is a hollow cylindrical vessel. The thermal storage tank (62) may be an open vessel. The thermal storage medium is accumulated in the thermal storage tank (62). An outflow pipe (65) is connected to an upper portion of the thermal storage tank (62) to allow the thermal storage medium in the thermal storage tank (62) to flow out of the tank. An inflow pipe (66) is connected to a lower portion of the thermal storage tank (62), for leading the thermal storage medium present outside the thermal storage tank (62) into the thermal storage tank (62). In other words, in the thermal storage tank (62), the junction of the outflow pipe (65) is located higher than the junction of the inflow pipe (66). A preheating-side thermal storage channel (64a), a pump (67), and a thermal storage-side thermal storage channel (63a) are connected to the thermal storage circuit (61) so as to be arranged sequentially from the outflow pipe (65) toward the inflow pipe (66).

[0066] The preheating heat exchanger (64) is configured to exchange heat between the thermal storage medium flowing through the preheating-side thermal storage channel (64a) and the refrigerant flowing through the preheating-side refrigerant channel (64b). The thermal storage heat exchanger (63) is configured to exchange heat between the thermal storage medium flowing through the thermal storage-side thermal storage channel (63a) and the refrigerant flowing through the thermal storage-side refrigerant channel (63b). The pump (67) is configured to circulate the thermal storage medium in the thermal storage circuit (61).

[Thermal Storage Medium]

[0067] Now, the thermal storage medium filling the thermal storage circuit (61) will be described in detail. A

thermal storage material in which clathrate hydrates are generated when cooled, that is, a thermal storage material having flow properties, is adopted as the thermal storage medium. The thermal storage medium can be such a medium in which a solid component is generated when cooled to a temperature higher than 0°C and lower than 20°C, for example. The solid component is a component which undergoes phase transitions (i.e., latent heat changes) from liquid at its melting point and is generating heat. Examples of the thermal storage medium include tetra-n-butyl ammonium bromide (TBAB) aqueous solution, trimethylolethane (TME) aqueous solution, and paraffin-based slurry. For example, the state as an aqueous solution of a tetra-n-butyl ammonium bromide aqueous solution is maintained even if it is cooled in a stable manner and turns into a subcooled state in which the temperature of the aqueous solution is lower than a hydrate formation temperature. However, once some trigger is given in this subcooled state, the subcooled solution transitions to a solution containing clathrate hydrates (i.e., transitions to slurry). That is, the subcooled state of the tetra-n-butyl ammonium bromide aqueous solution is changed to the state of slurry with relatively high viscosity due to the generation of clathrate hydrates (hydrate crystals) made of tetra-n-butyl ammonium bromide and water molecules. The subcooled state as used herein refers to a state in which clathrate hydrates are not generated and the state of solution is maintained even when the thermal storage medium reaches a temperature lower than or equal to the hydrate formation temperature. On the other hand, the tetra-n-butyl ammonium bromide aqueous solution in the state of slurry is changed to the state of liquid (i.e., a solution) with relatively high flow properties due to melting of the clathrate hydrates, if the temperature of the aqueous solution becomes higher, by heating, than the hydrate formation temperature.

[0068] In the present embodiment, a tetra-n-butyl ammonium bromide aqueous solution containing tetra-n-butyl ammonium bromide is adopted as the thermal storage medium. In particular, it is recommended that the thermal storage medium has a concentration close to a congruent concentration. In the present embodiment, the congruent concentration is set to about 40%. In this case, the hydrate formation temperature of the tetra-n-butyl ammonium bromide aqueous solution is about 12°C.

<Indoor Unit>

[0069] Each of the plurality of indoor units (70) includes the indoor circuit (71) which forms part of the refrigerant circuit (11). The plurality of indoor circuits (71) are connected in parallel with each other between the communication pipe (15) (a liquid pipe) and the communication pipe (16) (a gas pipe). The plurality of indoor circuits (71) and the above-described primary thermal storage channel (44) are connected in parallel with one another between the liquid line (L1) and the gas line (L2). The indoor heat exchanger (72) and the indoor expansion valve (73)

are connected to each indoor circuit (71) so as to be arranged sequentially from the gas-side end toward the liquid-side end.

[Indoor Heat Exchanger]

[0070] The indoor heat exchanger (72) is configured, for example, as a cross-fin-and-tube heat exchanger. An indoor fan (74) is provided adjacent to the indoor heat exchanger (72). The indoor heat exchanger (72) exchanges heat between the air transferred by the indoor fan (74) and the refrigerant flowing through the outdoor heat exchanger (23).

[Indoor Expansion Valve]

[0071] The indoor expansion valve (73) is arranged between a liquid-side end of the indoor heat exchanger (72) and the connection end of the communication pipe (15). The indoor expansion valve (73) is configured, for example, as an electronic expansion valve, and adjusts the flow rate of the refrigerant by changing the degree of opening of the valve.

<Controller>

[0072] The controller (100) serves as an operation control section which controls various devices. Specifically, the controller (100) switches between ON and OFF states of the compressor (22), switches between the states of the four-way switching valve (25), switches between opening and closing of each of the solenoid valves (SV1-SV6), adjusts the degree of opening of each of the expansion valves (24, 45, 73) and the pressure-reducing valves (EV1-EV4), switches between ON and OFF states of the fans (26, 74), switches between ON and OFF states of the pump (67), etc. The thermal storage air conditioner (10) is further provided with various types of sensors not shown. The controller (100) controls the various devices, based on values detected by these sensors.

<Operation of Thermal Storage Air Conditioner>

[0073] Operations of the thermal storage air conditioner (10) according to the first embodiment will be described. The thermal storage air conditioner (10) selectively performs a simple cooling operation, a cold thermal energy storage operation, a utilization cooling operation, a cooling and cold thermal energy storage operation, a simple heating operation, a warm thermal energy storage operation, a utilization heating operation, and a heating and warm thermal energy storage operation. The controller (100) controls various devices to switch between these operations.

[Simple Cooling Operation]

[0074] In the simple cooling operation, the thermal stor-

age device (60) is stopped, and the indoor unit (70) cools the room. In the simple cooling operation illustrated in FIG. 2, the four-way switching valve (25) is in the first state, and the second solenoid valve (SV2), the fourth solenoid valve (SV4), and the fifth solenoid valve (SV5) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The second pressure-reducing valve (EV2) and the fourth pressure-reducing valve (EV4) are fully closed. The outdoor expansion valve (24) is fully open. The degrees of opening of the first pressure-reducing valve (EV1) and the indoor expansion valve (73) are appropriately adjusted. The compressor (22), the outdoor fan (26) and the indoor fan (74) are actuated. The thermal storage device (60) is not actuated since the pump (67) is stopped. In the simple cooling operation, the refrigerant circuit (11) performs a refrigeration cycle in which the outdoor heat exchanger (23) serves as a condenser, the first subcooling heat exchanger (32) as a subcooler, and the indoor heat exchanger (72) as an evaporator. In the simple cooling operation, the low-pressure gas line (L2) and the primary thermal storage channel (44) communicate with each other. Liquid accumulation in the primary thermal storage channel (44) may thus be prevented.

[0075] The refrigerant discharged from the compressor (22) is condensed by the outdoor heat exchanger (23). A large part of the condensed refrigerant flows through the second heat transfer channel (34). The rest of the condensed refrigerant has its pressure reduced by the first pressure-reducing valve (EV1) and then flows through the first heat transfer channel (33). In the first subcooling heat exchanger (32), the refrigerant in the second heat transfer channel (34) is cooled by the refrigerant in the first heat transfer channel (33). The refrigerant which has flowed into the liquid line (L1) has its pressure reduced by the indoor expansion valve (73), and then evaporates in the indoor heat exchanger (72). The refrigerant flowing through the gas line (L2) merges with the refrigerant which has flowed into the first introduction pipe (31), and is taken into the compressor (22).

[Cold Thermal Energy Storage Operation]

[0076] In the cold thermal energy storage operation, the thermal storage device (60) is actuated to store cold thermal energy in the thermal storage medium in the thermal storage tank (62). In the cold thermal energy storage operation illustrated in FIG. 3, the four-way switching valve (25) is in the first state, and the second solenoid valve (SV2), the third solenoid valve (SV3), and the fourth solenoid valve (SV4) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The first pressure-reducing valve (EV1), the second pressure-reducing valve (EV2), the third pressure-reducing valve (EV3), the fourth pressure-reducing valve (EV4), and the indoor expansion valve (73) are fully closed. The outdoor expansion valve (24) is fully open. The degree of opening of the thermal stor-

age expansion valve (45) is appropriately adjusted. The compressor (22) and the outdoor fan (26) are actuated, and the indoor fan (74) is stopped. The thermal storage device (60) is actuated since the pump (67) is in operation. In the cold thermal energy storage operation, the refrigerant circuit (11) performs a refrigeration cycle in which the outdoor heat exchanger (23) serves as a condenser, the preheating heat exchanger (64) as a radiator (a refrigerant cooler), and the thermal storage heat exchanger (63) as an evaporator. In the cold thermal energy storage operation, a surplus refrigerant may be held in the channel extending from the high-pressure liquid line (L1) to the indoor unit (70).

[0077] The refrigerant discharged from the compressor (22) is condensed by the outdoor heat exchanger (23). The condensed refrigerant flows through the preheating-side refrigerant channel (64b) of the primary thermal storage channel (44). In the preheating heat exchanger (64), the thermal storage medium is heated by the refrigerant. Cores (fine crystals) of the clathrate hydrates which have flowed out of the thermal storage tank (62) are thus melted. The refrigerant cooled in the preheating-side refrigerant channel (64b) has its pressure reduced in the preheating heat exchanger (64), and then flows through the thermal storage-side refrigerant channel (63b). In the thermal storage heat exchanger (63), the thermal storage medium is cooled by the refrigerant and evaporates. The refrigerant which has flowed into the gas line (L2) from the primary thermal storage channel (44) is taken into the compressor (22). The thermal storage medium cooled by the thermal storage heat exchanger (63) is accumulated in the thermal storage tank (62).

[Utilization Cooling Operation]

[0078] In the utilization cooling operation, the thermal storage device (60) is actuated, and the cold thermal energy of the thermal storage medium stored in the thermal storage tank (62) is utilized to cool the room. In the utilization cooling operation illustrated in FIG. 4, the four-way switching valve (25) is in the first state, and the third solenoid valve (SV3), the fifth solenoid valve (SV5), and the sixth solenoid valve (SV6) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The first pressure-reducing valve (EV1) and the fourth pressure-reducing valve (EV4) are fully closed. The outdoor expansion valve (24) is fully open. The degrees of opening of the second pressure-reducing valve (EV2) and the indoor expansion valve (73) are appropriately adjusted. The compressor (22), the outdoor fan (26) and the indoor fan (74) are actuated. The thermal storage device (60) is actuated since the pump (67) is in operation. In the utilization cooling operation, the refrigerant circuit (11) performs a refrigeration cycle in which the outdoor heat exchanger (23) serves as a condenser, the preheating heat exchanger (64), the thermal storage heat exchanger (63), and the second sub-

cooling heat exchanger (52) as radiators (refrigerant coolers), and the indoor heat exchanger (72) as an evaporator.

[0079] The refrigerant discharged from the compressor (22) is condensed by the outdoor heat exchanger (23). The condensed refrigerant is cooled by the preheating heat exchanger (64) of the primary thermal storage channel (44), passes through the first bypass pipe (44a), and further cooled by the thermal storage heat exchanger (63). A large part of the refrigerant which has flowed through the primary thermal storage channel (44) and the third branch pipe (49) into the liquid line (L1) flows through the fourth heat transfer channel (54). The rest of the refrigerant has its pressure reduced by the second pressure-reducing valve (EV2) and then flows through the third heat transfer channel (53). In the second subcooling heat exchanger (52), the refrigerant flowing through the fourth heat transfer channel (54) is cooled by the refrigerant in the third heat transfer channel (53). The refrigerant cooled by the second subcooling heat exchanger (52) has its pressure reduced by the indoor expansion valve (73), and then evaporates in the indoor heat exchanger (72). The refrigerant flowing through the gas line (L2) merges with the refrigerant which has flowed out of the second introduction pipe (51), and is taken into the compressor (22).

[Cooling and Cold Thermal Energy Storage Operation]

[0080] In the cooling and cold thermal energy storage operation, the thermal storage device (60) is actuated to store cold thermal energy in the thermal storage medium, and the room is cooled by the indoor unit (70). In the cooling and cold thermal energy storage operation illustrated in FIG. 5, the four-way switching valve (25) is in the first state, and the second solenoid valve (SV2), the third solenoid valve (SV3), and the fourth solenoid valve (SV4) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The first pressure-reducing valve (EV1), the third pressure-reducing valve (EV3) and the fourth pressure-reducing valve (EV4) are fully closed. The outdoor expansion valve (24) is fully open. The degrees of opening of the second pressure-reducing valve (EV2), the thermal storage expansion valve (45), and the indoor expansion valve (73) are appropriately adjusted. The compressor (22), the outdoor fan (26) and the indoor fan (74) are actuated. The thermal storage device (60) is actuated since the pump (67) is in operation. In the refrigerant circuit (11) in the cooling and cold thermal energy storage operation, the outdoor heat exchanger (23) serves as a condenser, the preheating heat exchanger (64) and the second subcooling heat exchanger (52) as radiators (refrigerant coolers), and the thermal storage heat exchanger (63) and the indoor heat exchanger (72) as evaporators.

[0081] The refrigerant discharged from the compressor (22) is condensed by the outdoor heat exchanger (23). The condensed refrigerant flows through the sec-

ond heat transfer channel (34) and is diverged into the primary thermal storage channel (44) and the primary liquid pipe (42). The refrigerant in the primary thermal storage channel (44) heats the thermal storage medium in the preheating heat exchanger (64), and has its pressure reduced by the thermal storage expansion valve (45). A large part of the refrigerant in the primary liquid pipe (42) flows through the fourth heat transfer channel (54), and the rest of the refrigerant has its pressure reduced by the second pressure-reducing valve (EV2) and then flows through the third heat transfer channel (53). In the second subcooling heat exchanger (52), the refrigerant flowing through the fourth heat transfer channel (54) is cooled by the refrigerant in the third heat transfer channel (53). The refrigerant cooled by the second subcooling heat exchanger (52) has its pressure reduced by the indoor expansion valve (73), and then evaporates in the indoor heat exchanger (72). The refrigerant flowing through the gas line (L2) merges with the refrigerant which has flowed out of the second introduction pipe (51), and is taken into the compressor (22).

[Simple Heating Operation]

[0082] In the simple heating operation, the thermal storage device (60) is stopped, and the indoor unit (70) heats the room. In the simple heating operation illustrated in FIG. 6, the four-way switching valve (25) is in the second state, and the second solenoid valve (SV2) among the first to sixth solenoid valves (SV1-SV6) is open. The rest of the solenoid valves are closed. The first to fourth pressure-reducing valves (EV1-EV4) and the thermal storage expansion valve (45) are fully closed. The degrees of opening of the indoor expansion valve (73) and the outdoor expansion valve (24) are appropriately adjusted. The compressor (22), the outdoor fan (26) and the indoor fan (74) are actuated. The thermal storage device (60) is not actuated since the pump (67) is stopped. In the simple heating operation, the refrigerant circuit (11) performs a refrigeration cycle in which the indoor heat exchanger (72) serves as a condenser, and the outdoor heat exchanger (23) as an evaporator. The indoor expansion valve (73) controls the degree of subcooling of the refrigerant at the exit of the indoor heat exchanger (72).

[0083] The refrigerant discharged from the compressor (22) flows through the gas line (L2) and is condensed by the indoor heat exchanger (72). The refrigerant which has flowed into the liquid line (L1) has its pressure reduced by the outdoor expansion valve (24), and then evaporates in the outdoor heat exchanger (23) and is taken into the compressor (22).

[Warm Thermal Energy Storage Operation]

[0084] In a warm thermal energy storage operation, the thermal storage medium in which warm thermal energy is stored is accumulated in the thermal storage tank

(62). In the warm thermal energy storage operation illustrated in FIG. 7, the four-way switching valve (25) is in the second state, and the third solenoid valve (SV3), the fourth solenoid valve (SV4), and the fifth solenoid valve (SV5) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The first to fourth pressure-reducing valves (EV1-EV4) and the indoor expansion valve (73) are fully closed. The degree of opening of the outdoor expansion valve (24) is appropriately adjusted. The compressor (22) and the outdoor fan (26) are actuated, and the indoor fan (74) is stopped. The thermal storage device (60) is actuated since the pump (67) is in operation. In the warm thermal energy storage operation, the refrigerant circuit (11) performs a refrigeration cycle in which the thermal storage heat exchanger (63) and the preheating heat exchanger (64) serve as condensers, and the outdoor heat exchanger (23) as an evaporator.

[0085] The refrigerant discharged from the compressor (22) passes through the gas line (L2), dissipates heat in the thermal storage heat exchanger (63), passes through the second bypass pipe (44a), and then further dissipates heat in the preheating heat exchanger (64). The refrigerant which has flowed out of the primary thermal storage channel (44) has its pressure reduced by the outdoor expansion valve (24), and then evaporates in the outdoor heat exchanger (23) and is taken into the compressor (22). The thermal storage medium heated by the thermal storage heat exchanger (63) and the preheating heat exchanger (64) is accumulated in the thermal storage tank (62).

[First Utilization Heating Operation]

[0086] In the first utilization cooling operation (or the utilization heating operation (1)), the thermal storage device (60) is actuated, and the warm thermal energy of the thermal storage medium stored in the thermal storage tank (62) is utilized to heat the room. Although details will be described later, the stored warm thermal energy is not used at once, but usable for a long period of time, in the first utilization heating operation even under a condition in which the heating load is relatively high. The power consumption may thus be reduced. In the utilization heating operation illustrated in FIG. 8, the four-way switching valve (25) is in the second state, the first solenoid valve (SV1), the second solenoid valve (SV2), and the fifth solenoid valve (SV5) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The first to third pressure-reducing valves (EV1-EV3) are fully closed. The degrees of opening of the fourth pressure-reducing valve (EV4), the indoor expansion valve (73) and the outdoor expansion valve (24) are appropriately adjusted. The compressor (22), the outdoor fan (26) and the indoor fan (74) are actuated. The thermal storage device (60) is actuated since the pump (67) is in operation. In the utilization heating operation, the refrigerant circuit (11) performs a re-

frigeration cycle in which the indoor heat exchanger (72) serves as a condenser, and the thermal storage heat exchanger (63) and the outdoor heat exchanger (23) as evaporators.

[0087] The refrigerant discharged from the compressor (22) flows through the gas line (L2) and is condensed by the indoor heat exchanger (72). The refrigerant which has flowed into the liquid line (L1) is diverged into the second branch pipe (48) and the primary liquid pipe (42). The refrigerant in the second branch pipe (48) has its pressure reduced by the fourth pressure-reducing valve (EV4) to an intermediate pressure (between a high pressure and a low pressure in the refrigerant circuit (11)) and flows into the primary thermal storage channel (44). The refrigerant in the primary thermal storage channel (44) is heated in the thermal storage heat exchanger (63) and the preheating heat exchanger (64) and evaporates. The evaporated refrigerant sequentially passes through the intermediate junction pipe (46), the communication pipe (13), and the intermediate suction pipe (35), and is taken into the compression chamber of the compressor (22) in the middle of the compression process.

[0088] The refrigerant in the primary liquid pipe (42) has its pressure reduced by the outdoor expansion valve (24), evaporates in the outdoor heat exchanger (23), and is taken into the suction pipe (28) of the compressor (22). In the compression chamber of the compressor (22), the low-pressure refrigerant taken through the suction pipe (28) is compressed to an intermediate pressure, mixed with the intermediate-pressure refrigerant taken through the intermediate suction pipe (35), and then compressed to have a high pressure.

[Heating and Warm Thermal Energy Storage Operation]

[0089] In the heating and warm thermal energy storage operation, the thermal storage device (60) is actuated to store warm thermal energy in the thermal storage tank (62), and the room is heated by the indoor unit (70). In the heating and warm thermal energy storage operation illustrated in FIG. 9, the four-way switching valve (25) is in the second state, and the second solenoid valve (SV2), the third solenoid valve (SV3), the fourth solenoid valve (SV4), and the fifth solenoid valve (SV5) among the first to sixth solenoid valves (SV1-SV6) are open. The first pressure-reducing valve (EV1), the second pressure-reducing valve (EV2), the third pressure-reducing valve (EV3) and the fourth pressure-reducing valve (EV4) are fully closed. The degrees of opening of the indoor expansion valve (73), the thermal storage expansion valve (45) and the outdoor expansion valve (24) are appropriately adjusted. The compressor (22), the outdoor fan (26) and the indoor fan (74) are actuated. The thermal storage device (60) is actuated since the pump (67) is in operation. In the warm thermal energy storage operation, the refrigerant circuit (11) performs a refrigeration cycle in which the indoor heat exchanger (72), the thermal storage heat exchanger (63), and the preheating heat ex-

changer (64) serve as condensers, and the outdoor heat exchanger (23) as an evaporator.

[0090] The refrigerant discharged from the compressor (22) flows through the gas line (L2), and is diverged into the primary thermal storage channel (44) and the indoor circuit (71). The refrigerant in the primary thermal storage channel (44) dissipates heat to the thermal storage medium in the preheating heat exchanger (64) and the thermal storage heat exchanger (63). The refrigerant in the indoor circuit (71) is condensed in the indoor heat exchanger (72). The refrigerant which has flowed out of the indoor circuit (71) and the refrigerant which has flowed out of the primary thermal storage channel (44) are mixed with each other in the liquid line (L1). The mixed refrigerant has its pressure reduced by the outdoor expansion valve (24), evaporates in the outdoor heat exchanger (23), and is taken into the compressor (22).

[Details of Utilization Heating Operation]

[0091] Details of the utilization heating operation of the thermal storage air conditioner (10) according to the first embodiment will be described. The thermal storage air conditioner (10) performs the above-described first utilization heating operation (or the utilization heating operation (1)) as an operation in which the warm thermal energy of the thermal storage medium is utilized to heat the room. The thermal storage air conditioner (10) performs a second utilization heating operation, which will be described below, in addition to the utilization heating operation (1). More specifically, the second utilization heating operation may be roughly grouped into a utilization heating operation (2), a utilization heating operation (3), and a utilization heating operation (4).

[Detailed Behaviors of Utilization Heating Operation (1)]

[0092] Further details of the utilization heating operation (1) will be described.

[0093] The utilization heating operation (1) is performed under a condition in which a difference (MP-LP) is relatively large between a pressure (MP) of the refrigerant which evaporates in the thermal storage heat exchanger (63) and a pressure (LP) of the refrigerant which evaporates in the outdoor heat exchanger (23). For example, this condition is met in a situation in a winter season in which a temperature of the outside air is relatively low, but a temperature of the thermal storage medium in the thermal storage circuit (61) of the thermal storage device (60) is relatively high. If the condition indicating that the difference MP-LP is greater than a predetermined value is met, the thermal storage air conditioner (10) performs the utilization heating operation (1). Examples of this condition may include a condition in which a difference Ta-To between a temperature Ta of the thermal storage medium and a temperature To of the outdoor air is greater than the predetermined value. The temperatures Ta and To are detected by a temperature sensor

(not shown).

[0094] If this condition is met, the utilization heating operation (1) is performed. In the utilization heating operation (1) illustrated in FIG. 8, part of the refrigerant condensed in the indoor heat exchanger (72) has its pressure reduced by the fourth pressure-reducing valve (EV4) to an intermediate pressure, and flows through the thermal storage-side refrigerant channel (63b) of the thermal storage heat exchanger (63). For example, the degree of opening of the fourth pressure-reducing valve (EV4) is adjusted such that a degree of superheat SH1 of the refrigerant which has passed through the thermal storage-side refrigerant channel (63b) is a predetermined value. Thus, the evaporating pressure MP1 of the refrigerant in the thermal storage-side refrigerant channel (63b) is relatively high under a condition in which the temperature Ta of the thermal storage medium is relatively high. The refrigerant which has evaporated in the thermal storage-side refrigerant channel (63b) passes through the fully-opened thermal storage expansion valve (45) and the preheating-side refrigerant channel (64b) of the preheating heat exchanger (64), and flows through the intermediate suction pipe (35).

[0095] On the other hand, the rest of the refrigerant which has been condensed in the indoor heat exchanger (72) has its pressure reduced by the outdoor expansion valve (24) to a low pressure, and flows through the outdoor heat exchanger (23). In the outdoor heat exchanger (23), the refrigerant absorbs heat from the outdoor air and evaporates. For example, the degree of opening of the outdoor expansion valve (24) is adjusted such that a degree of superheat SH2 of the refrigerant which has passed through the outdoor heat exchanger (23) is a predetermined value. Thus, the evaporating pressure LP of the refrigerant in the outdoor heat exchanger (23) is relatively low under a condition in which the temperature To of the outdoor air is relatively low. As a result, in the utilization heating operation (1), a refrigeration cycle in which the difference MP-LP is greater than the predetermined value is performed.

[0096] The refrigerant having the low pressure LP is taken into the compressor (22) through the suction pipe (28). This refrigerant is compressed in the compression chamber of the compression mechanism. Simultaneously, the refrigerant having the intermediate pressure MP is taken into the compressor (22) through the intermediate suction pipe (35). This intermediate pressure refrigerant is compressed in the compression chamber of the compression mechanism. Since the difference MP-LP is relatively great, the possibility that the internal pressure of the compression chamber in the middle of the compression process becomes higher than the pressure of the refrigerant to be introduced therein through the intermediate suction pipe (35) may be reduced. Thus, the refrigerant in the intermediate suction pipe (35) may be reliably introduced in the compression chamber.

[0097] Moreover, the intermediate suction pipe (35) is provided with the check valve (CV1) which prohibits the

back-flow of the refrigerant from the compressor (22) toward the primary thermal storage channel (44). Thus, even if the pressure MP of the refrigerant flowing out of the intermediate suction pipe (35) is lower than the internal pressure of the compression chamber in the middle of the compression process, the refrigerant in the compression chamber does not flow back into the intermediate suction pipe (35).

[0098] Further, compressing the refrigerant under the condition in which the difference MP-LP is relatively great reduces the overall workloads required for the compressor (22) to compress the refrigerant to a high pressure. As a result, the utilization heating operation (1) may achieve energy-efficient heating, while giving the warm thermal energy of the thermal storage medium to the refrigerant.

[0099] In addition, in the utilization heating operation (1), only part of the refrigerant condensed in the indoor heat exchanger (72) is introduced into the primary thermal storage channel (44). That is, in the utilization heating operation (1), the mass flow rate of the refrigerant flowing through the thermal storage heat exchanger (63) is relatively small. Thus, in the thermal storage device (60), the amount of warm thermal energy stored in the thermal storage medium is not reduced rapidly. In other words, the amount of warm thermal energy (i.e., the amount of thermal energy stored) that should be stored in order to perform the utilization heating operation (1) may be reduced to a relatively small amount. This configuration allows for downsizing of the thermal storage tank (62) used to store the thermal storage medium.

[Second Utilization Heating Operation]

[0100] The second utilization heating operation is performed under a condition in which the above-described difference MP-LP is relatively small. For example, this condition is met in a situation in a winter season in which a temperature To of the outside air is relatively high, but a temperature Ta of the thermal storage medium in the thermal storage circuit (61) of the thermal storage device (60) is relatively low. If the condition indicating that the difference MP-LP is smaller than a predetermined value is met, the thermal storage air conditioner (10) performs the second utilization heating operation. Examples of this condition may include a condition in which the difference Ta-To is smaller than the predetermined value. If this condition is met, the second utilization heating operation is performed. Specifically, the second utilization heating operation may be roughly grouped into a utilization heating operation (2), a utilization heating operation (3), and a utilization heating operation (4) which will be described below.

[Utilization Heating Operation (2)]

[0101] In the utilization heating operation (2) illustrated in FIG. 10, the four-way switching valve (25) is in the

second state, and the third solenoid valve (SV3) and the fifth solenoid valve (SV5) among the first to sixth solenoid valves (SV1-SV6) are open. The rest of the solenoid valves are closed. The first pressure-reducing valve (EV1) and the outdoor expansion valve (24) are fully open. The second pressure-reducing valve (EV2) and the third pressure-reducing valve (EV3) are fully closed. The degree of opening of the fourth pressure-reducing valve (EV4) and the indoor expansion valve (73) are appropriately adjusted. The compressor (22) and the indoor fan (74) are actuated, and the outdoor fan (26) is stopped. The thermal storage device (60) is actuated since the pump (67) is in operation. In the utilization heating operation (2), the refrigerant circuit (11) performs a refrigeration cycle in which the indoor heat exchanger (72) serves as a condenser, and the thermal storage heat exchanger (63) as an evaporator.

[0102] The refrigerant discharged from the compressor (22) flows through the gas line (L2) and is condensed by the indoor heat exchanger (72). All of the refrigerant which has flowed into the liquid line (L1) flows in the second branch pipe (48). In the second branch pipe (48), the pressure of the refrigerant is reduced to a low pressure by the fourth pressure-reducing valve (EV4). The pressure-reduced refrigerant flows through the thermal storage-side refrigerant channel (63b) of the thermal storage heat exchanger (63), and absorbs heat from the thermal storage medium and evaporates. The refrigerant which has evaporated in the thermal storage heat exchanger (63) passes through the first bypass pipe (44a), flows through the preheating-side refrigerant channel (64b) of the preheating heat exchanger (64), and absorbs heat from the thermal storage medium and further evaporates. This refrigerant flows through the primary thermal storage channel (44) and is diverged into the first introduction pipe (31) and the outdoor heat exchanger (23). These refrigerants merge with each other in the suction pipe (28), and the merged refrigerant is taken into the compressor (22).

[0103] In this manner, the refrigerant to which the warm thermal energy is given in the thermal storage heat exchanger (63) is taken into the suction pipe (28) on the low pressure side of the compressor (22) through the first introduction pipe (31) and the outdoor heat exchanger (23) under the condition in which the difference MP-LP is relatively small. Thus, the room can be heated, while reliably utilizing the warm thermal energy of the thermal storage medium, even under a condition in which the refrigerant cannot be introduced in the compression chamber from the intermediate suction pipe (35).

[0104] Further, the first introduction pipe (31) through which the refrigerant evaporated in the thermal storage heat exchanger (63) flows also serves as part of the first subcooling circuit (30). Thus, the number of pipes of the refrigerant circuit (11) may be reduced. The refrigerant which has evaporated in the thermal storage heat exchanger (63) flows through the outdoor heat exchanger (23), as well. Thus, the pressure loss of the gas refriger-

ant, as well as the power to actuate the compressor (22), may be reduced. In addition, the heat loss of the refrigerant may be minimized in the outdoor heat exchanger (23) because the outdoor fan (26) is stopped.

[Utilization Heating Operation (3)]

[0105] The following utilization heating operation (3) may be performed instead of the utilization heating operation (2). Unlike the utilization heating operation (2), the outdoor expansion valve (24) is fully closed in the utilization heating operation (3) illustrated in FIG. 11. Thus, the refrigerant which has flowed out of the primary thermal storage channel (44) flows only through the first introduction pipe (31), and is taken into the compressor (22). The refrigerant which has flowed out of the primary thermal storage channel (44) does not pass through the outdoor heat exchanger (23) in the utilization heating operation (3). The refrigerant passing through the outdoor heat exchanger (23) dissipates heat to the outdoor air. Thus, heat loss may easily occur. However, the first subcooling heat exchanger (32) is a type of heat exchanger which allows a refrigerant to exchange heat with a refrigerant. Thus, even if the refrigerant flows through the first introduction pipe (31), there is not much heat loss. The outdoor fan (26) is stopped in the utilization heating operation (3), as well, which may reduce the power required to actuate the fan.

[Utilization Heating Operation (4)]

[0106] The following utilization heating operation (4) may be performed instead of the utilization heating operation (2) and/or (3). Unlike the utilization heating operation (2), the first pressure-reducing valve (EV1) is fully closed in the utilization heating operation (4) illustrated in FIG. 12. Thus, all the refrigerant which has flowed out of the primary thermal storage channel (44) passes through the outdoor heat exchanger (23), and is taken into the compressor (22). The heat loss of the refrigerant may be minimized in the outdoor heat exchanger (23) because the outdoor fan (26) is stopped.

-Advantages of First Embodiment-

[0107] According to the first embodiment, only part of the refrigerant which has been condensed in the indoor heat exchanger (72) evaporates in the thermal storage heat exchanger (63) in the first utilization heating operation. Thus, the power consumption of a heating operation may be reduced for a relatively long period of time. The refrigerant which has evaporated in the thermal storage heat exchanger (63) is taken into the compression chamber of the compressor (22) in the middle of the compression process. Thus, the compression workloads of the compressor (22) may be reduced, and the energy efficiency of the thermal storage air conditioner (10) may be improved. The compression efficiency of the compres-

sor (22) may also be improved because the degree of superheat of the refrigerant taken into the compressor (22) does not become excessively large.

[0108] The first utilization heating operation is performed under a condition in which the difference (MP-LP) is relatively large between an evaporating pressure MP of the refrigerant in the thermal storage section (60) and an evaporating pressure LP of the refrigerant in the outdoor heat exchanger (23). Thus, the refrigerant having an intermediate pressure may be reliably introduced in the compression chamber, and the compression workloads of the compressor (22) may be effectively reduced.

[0109] Since the check valve (CV1) is provided on the intermediate suction pipe (35), it is possible to reliably prevent back-flow of the refrigerant in the intermediate suction pipe (35) during the first utilization heating operation. Thus, the warm thermal energy of the thermal storage medium may be utilized to heat the room with reliability.

[0110] The second utilization heating operation is performed under a condition in which the difference MP-LP is relatively small. Thus, the heating operation can be performed, while reliably utilizing the warm thermal energy of the thermal storage medium, even under a condition in which the refrigerant having an intermediate pressure is hard to be introduced in the compression chamber.

[0111] The first introduction pipe (31) of the first sub-cooling circuit (30) also serves as a flow channel for sub-cooling in the simple cooling operation, and as a flow channel for taking the refrigerant which has evaporated in the thermal storage heat exchanger (63) in the utilization heating operation (2) and/or (3) into the suction pipe (28) of the compressor (22). Thus, the number of pipes of the refrigerant circuit (11) may be reduced.

[0112] In the utilization heating operation (2), the refrigerant which has evaporated in the thermal storage heat exchanger (63) flows to both of the low-pressure introduction pipe (31) and the outdoor heat exchanger (23), and is transferred to the suction pipe (28) of the compressor (22). Thus, the pressure loss of the refrigerant, as well as the power to actuate the compressor (22) may be reduced, compared with a case in which the refrigerant flows into only one of the introduction pipe (31) or the outdoor heat exchanger (23).

[0113] In the utilization heating operation (3), the refrigerant which has evaporated in the thermal storage heat exchanger (63) bypasses the outdoor heat exchanger (23) before it is taken into the suction pipe (28) of the compressor (22). Thus, the heat loss of the refrigerant with respect to the outdoor air may be minimized.

[0114] In the utilization heating operations (2) and (4), the outdoor fan (26) is stopped. Thus, the heat loss of the refrigerant in the outdoor heat exchanger (23) may be reduced reliably.

-Variation of First Embodiment-

[0115] In the first embodiment, the check valve (CV1) is provided at a portion of the intermediate suction pipe (35) located outside the casing (22a) of the compressor (22). This configuration facilitates the connection and maintenance of the check valve (CV1). The check valve (CV1) may be provided at the inner pipe portion (36) of the intermediate suction pipe (35) located inside the casing (22a). This configuration may achieve a minimum channel length from the compression chamber of the compression mechanism in the middle of the compression process to the check valve (CV1), thereby minimizing a dead volume that does not contribute to the compression of the refrigerant. As a result, decline in the compression efficiency of the compressor (22) may be prevented.

(Second Embodiment of The Invention)

[0116] A thermal storage air conditioner (10) according to a second embodiment of the present invention performs a two-stage compression refrigeration cycle in the refrigerant circuit (11). That is, the thermal storage air conditioner (10) is designed for use in a cold climate area, for example, and has a higher rated capacity of heating than the thermal storage air conditioner of the first embodiment. Elements of the thermal storage air conditioner (10) according to the second embodiment which are different from those of the first embodiment will be described below.

<General Configuration>

[0117] As illustrated in FIG. 13, a compressor section (80) of the second embodiment is of a two-stage compression type comprised of a first compressor (81) and a second compressor (82). The first compressor (81) serves as a low-stage compressor. The second compressor (82) serves as a high-stage compressor. The first compressor (81) is connected to the outdoor circuit (21). A low-stage discharge pipe (83) through which a compressed intermediate-pressure refrigerant is discharged, and a low-stage suction pipe (84) (or a low-pressure suction portion) into which a low-pressure refrigerant is taken are connected to the first compressor (81). The second compressor (82) is connected to the intermediate circuit (41). A high-stage discharge pipe (85) through which a compressed high-pressure refrigerant is discharged, and a high-stage suction pipe (86) into which an intermediate-pressure refrigerant is taken are connected to the second compressor (82).

[0118] That is, with the first compressor (81) and the second compressor (82) connected in series, the compressor section (80) serves as a compressor section of a two-stage compression type. Both compression mechanisms, i.e., the first compressor (81) and the second compressor (82), may be housed in a single casing to

serve as a compressor section of a two-stage compression type (i.e., the compressor (80)).

[0119] Both of the first compressor (81) and the second compressor (82) are comprised of an inverter compressor. Thus, the intermediate pressure of the refrigerant taken into the high-stage suction pipe (86) may be adjusted by adjusting the operational frequencies of the compressors (81, 82).

[0120] The intermediate suction pipe (35) is connected to the intermediate circuit (41). Specifically, the starting end of the intermediate suction pipe (35) is connected to the primary thermal storage channel (44) between the third solenoid valve (SV3) and the preheating-side refrigerant channel (64b). The terminal end of the intermediate suction pipe (35) is connected to the high-stage suction pipe (86).

[0121] An intermediate pipe (87) and a high-stage bypass pipe (88) are connected to the intermediate circuit (41). The intermediate pipe (87) connects the communication pipe (14) and the high-stage suction pipe (86). One end of the high-stage bypass pipe (88) is connected to the high-stage discharge pipe (85), and the other end of the high-stage bypass pipe (88) is connected to the intermediate suction pipe (35). A seventh solenoid valve (SV7) is connected to the high-stage bypass pipe (88). The seventh solenoid valve (SV7) is configured to be open in, for example, a cooling operation, so that the refrigerant bypasses the second compressor (82).

[0122] The thermal storage air conditioner (10) according to the second embodiment is configured by connecting a thermal storage unit (40) to the air conditioner (10a) installed already, as illustrated in FIG. 14. Specifically, in the already-installed air conditioner (10a) illustrated in FIG. 14, the outdoor unit (20) and the indoor unit (70) similar to those of the second embodiment are connected to each other via two communication pipes (15, 16). The thermal storage air conditioner (10) of the second embodiment is configured such that the thermal storage unit (40) intervenes between the outdoor unit (20) and the indoor unit (70).

<First Utilization Heating Operation>

[0123] A first utilization heating operation (i.e., a utilization heating operation (1)) of the thermal storage air conditioner (10) according to the second embodiment will be described with reference to FIG. 15. Basic behaviors of the utilization heating operation (1) of the second embodiment are similar to those of the utilization heating operation (1) of the first embodiment. However, in the utilization heating operation (1) of the second embodiment, both of the first compressor (81) and the second compressor (82) are actuated and the seventh solenoid valve (SV7) is closed. Similarly to the first embodiment, the utilization heating operation (1) is performed under a condition in which the difference MP-LP is relatively great.

[0124] The refrigerant which has been compressed to

an intermediate pressure in the first compressor (81) is taken into the second compressor (82) through the high-stage suction pipe (86). The refrigerant which has been compressed to a high pressure in the second compressor (82) dissipates heat in the indoor heat exchanger (72), and flows into the liquid line (L1). Part of the refrigerant in the liquid line (L1) has its pressure reduced to an intermediate pressure by the fourth pressure-reducing valve (EV4), evaporates in the thermal storage heat exchanger (63) and the preheating heat exchanger (64), and flows into the intermediate suction pipe (35).

[0125] The rest of the refrigerant in the liquid line (L1) has its pressure reduced to a low pressure by the outdoor expansion valve (24), evaporates in the outdoor heat exchanger (23), and taken into the first compressor (81). The refrigerant which has been compressed to an intermediate pressure in the first compressor (81) merges with the refrigerant in the high-stage suction pipe (86) introduced therein from the intermediate suction pipe (35), and is taken into the second compressor (82).

<Second Utilization Heating Operation>

[0126] A second utilization heating operation (which is referred to as a utilization heating operation (2) herein) of the thermal storage air conditioner (10) according to the second embodiment will be described with reference to FIG. 16. Basic behaviors of the second utilization heating operation of the second embodiment are similar to those of the second utilization heating operation of the first embodiment. Similarly to the first embodiment, the second utilization heating operation is performed under a condition in which the difference MP-LP is relatively small.

[0127] That is, in the utilization heating operation (2), the refrigerant which has been compressed in the first compressor (81) and the second compressor (82) are condensed in the indoor heat exchanger (72), and all of this refrigerant evaporates in the thermal storage heat exchanger (63) and the preheating heat exchanger (64). The evaporated refrigerant is diverged into the first introduction pipe (31) and the outdoor heat exchanger (23), merged together again, and taken into the first compressor (81).

[0128] In the second embodiment, as well, the refrigerant which has evaporated in the thermal storage heat exchanger (63) may flow only through the first introduction pipe (31) before the refrigerant is taken into the first compressor (81) (i.e., the utilization heating operation (3)). Further, all of the refrigerant which has evaporated in the thermal storage heat exchanger (63) may flow only through the outdoor heat exchanger (23) before the refrigerant is taken into the first compressor (81) (i.e., the utilization heating operation (4)). In the utilization heating operations (2) and (4), the outdoor fan (26) is stopped. Thus, the heat loss of the refrigerant with respect to the outdoor air may be minimized.

[0129] The other advantages of the second embodi-

ment are the same as, or similar to, those of the first embodiment.

<<Variation of Second Embodiment>>

[0130] A variation of the second embodiment is illustrated in FIG. 17, in which an intermediate injection circuit (90) (i.e., a so-called economizer circuit) is added to the intermediate circuit (41) of the second embodiment. The intermediate injection circuit (90) includes an intermediate introduction pipe (91) and an internal heat exchanger (92). One end of the intermediate introduction pipe (91) is connected to the primary liquid pipe (42) between the connection end of the communication pipe (12) and a sixth heat transfer channel (94). The other end of the intermediate introduction pipe (91) is connected to the intermediate suction pipe (35). The fifth pressure-reducing valve (EV5) and a fifth heat transfer channel (93) are connected to the intermediate introduction pipe (91) so as to be arranged sequentially from one end to the other end of the intermediate introduction pipe (91). The internal heat exchanger (92) forms a second heat exchanger which exchanges heat between the refrigerant in the fifth heat transfer channel (93) and the refrigerant in the sixth heat transfer channel (94). The other configurations are the same as, or similar to, those of the second embodiment.

[0131] In the first utilization heating operation (or the utilization heating operation (1)) of this variation, part of the refrigerant which has been condensed in the indoor heat exchanger (72) has its pressure reduced by the fourth pressure-reducing valve (EV4), and evaporates in the thermal storage heat exchanger (63). This refrigerant sequentially passes through the fully-opened thermal storage expansion valve (45) and the preheating-side refrigerant channel (64b), and flows into the intermediate suction pipe (35).

[0132] The rest of the refrigerant which has been condensed in the indoor heat exchanger (72) flows through the primary liquid pipe (42), and part of the refrigerant is diverged into the intermediate introduction pipe (91). The diverged refrigerant has its pressure reduced by the fifth pressure-reducing valve (EV5), and the wetness is adjusted. Specifically, the degree of opening of the fifth pressure-reducing valve (EV5) is adjusted such that the degree of superheat SH3 of the refrigerant taken into the second compressor (82) is smaller than, or equal to, a relatively small predetermined value α .

[0133] The refrigerant flowing into the intermediate suction pipe (35) from the primary thermal storage channel (44) has a relatively greater degree of superheat. Introducing the refrigerant having a relatively greater wetness from the intermediate introduction pipe (91) to the intermediate suction pipe (35) may therefore reduce the degree of superheat of the merged refrigerant, and allow this degree of superheat to be lower than, or equal to, the predetermined value α . In this manner, the refrigerant having a lower degree of superheat is introduced into the

high-stage compressor (82), which makes it possible to improve the efficiency of the high-stage compressor (82), and further increase the energy efficiency of the thermal storage air conditioner (10) in the first utilization heating operation.

[0134] Note that in this example, the degree of opening of the fifth pressure-reducing valve (EV5) is adjusted based on the degree of superheat SH3 of the refrigerant taken into the second compressor (82). The degree of opening of the fifth pressure-reducing valve (EV5) may also be adjusted based on the degree of superheat SH4 of the refrigerant going out of the fifth heat transfer channel (93) of the internal heat exchanger (92).

[0135] The other advantages are the same as, or similar to, those of the above-described second embodiment.

«Other Embodiments»

[0136] The thermal storage sections of the above embodiments are so-called dynamic thermal storage devices having a thermal storage circuit in which the thermal storage medium is circulated. However, the thermal storage sections may also be so-called static thermal storage devices in which water or other thermal storage media retained in a tank, for example, is heat-exchanged with a refrigerant.

INDUSTRIAL APPLICABILITY

[0137] As can be seen from the foregoing description, the present invention is useful as a thermal storage air conditioner.

DESCRIPTION OF REFERENCE CHARACTERS

[0138]

10	Thermal Storage Air Conditioner
11	Refrigerant Circuit
22	Compressor (Compression Section)
22a	Casing
23	Outdoor Heat Exchanger
28	Suction Pipe (Low-Pressure Suction Portion)
31	First Introduction Pipe (Low-Pressure Introduction Pipe)
32	First Subcooling Heat Exchanger (First Heat Exchanger)
35	Intermediate Suction Pipe (Intermediate Suction Portion)
36	Inner Pipe Portion
44	Primary Thermal Storage Channel
60	Thermal Storage Section (Thermal Storage Device)
61	Thermal Storage Circuit
62	Thermal Storage Tank
37	Thermal Storage Heat Exchanger
72	Indoor Heat Exchanger

- 80 Compressor Section (Two-Stage Compression Type)
- 81 First Compressor (Low-Stage Compressor)
- 82 Second Compressor (High-Stage Compressor)
- 84 Low-Stage Suction Pipe (Low-Pressure Suction Portion)
- 86 High-Stage Suction Pipe (Suction Pipe)
- 91 Intermediate Introduction Pipe
- 92 Internal Heat Exchanger (Second Heat Exchanger)
- EV1 First Pressure-Reducing Valve (Pressure-Reducing Valve)
- EV5 Fifth Pressure-Reducing Valve (Pressure-Reducing Valve)

Claims

1. A regenerative air conditioner comprising:

a refrigerant circuit (11) to which a compressor section (22, 80) which compresses a refrigerant, an outdoor heat exchanger (23), and an indoor heat exchanger (72) are connected; and a thermal storage section (60) in which heat is exchanged between the refrigerant in the refrigerant circuit (11) and a thermal storage medium, wherein the refrigerant circuit (11) includes

a primary thermal storage channel (44) to which the thermal storage section (60) is connected, and an intermediate suction portion (35) through which the refrigerant having an intermediate pressure between high and low pressures in the refrigerant circuit (11) is taken into the compressor section (22, 80), and

the refrigerant circuit (11) performs a first utilization heating operation in which part of the refrigerant which has been condensed in the indoor heat exchanger (72) is diverged into the primary thermal storage channel (44), is evaporated in the thermal storage section (60), and is then taken into the intermediate suction portion (35) of the compressor section (22, 80), and simultaneously, a rest of the refrigerant which has been condensed in the indoor heat exchanger (72) is evaporated in the outdoor heat exchanger (23) and then taken into a low-pressure suction portion (28, 84) of the compressor section (22, 80).

2. The regenerative air conditioner of claim 1, wherein the refrigerant circuit (11) performs a second utilization heating operation in which all of the refrigerant which has been condensed in the indoor heat ex-

changer (72) flows into the primary thermal storage channel (44), is evaporated in the thermal storage section (60), and is then taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

3. The regenerative air conditioner of claim 2, wherein the refrigerant circuit (11) includes a low-pressure introduction pipe (31) which communicates a liquid line (L1) of the refrigerant circuit (11) with the low-pressure suction portion (28, 84) of the compressor section (22, 80) and has a pressure-reducing valve (EV1), and a first heat exchanger (32) which, in a cooling operation, exchanges heat between the refrigerant having a pressure reduced by the pressure-reducing valve (EV1) of the low-pressure introduction pipe (31) and the refrigerant flowing through the liquid line (L1), and in the refrigerant circuit (11) in the second utilization heating operation, at least part of the refrigerant which has been evaporated in the thermal storage section (60) passes through the fully-opened pressure-reducing valve (EV1) of the low-pressure introduction pipe (31), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80).

4. The regenerative air conditioner of claim 3, wherein in the refrigerant circuit (11) in the second utilization heating operation, part of the refrigerant which has been evaporated in the thermal storage section (60) passes through the fully-opened pressure-reducing valve (EV1) of the low-pressure introduction pipe (31), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22, 80), and simultaneously, a rest of the refrigerant which has been evaporated in the thermal storage section (60) passes through the outdoor heat exchanger (23), and is taken into the low-pressure suction portion (28, 84) of the compressor section (22).

5. The regenerative air conditioner of claim 4, comprising:

an outdoor fan (26) which transfers air passing through the outdoor heat exchanger (23) and which is stopped in the second utilization heating operation.

6. The regenerative air conditioner of any one of claims 1-5, wherein the compressor section (22, 80) is configured as a single-stage compressor (22), and the intermediate suction portion (35) communicates with a compression chamber of the single-stage compressor (22) in the middle of a compression process.

7. The regenerative air conditioner of claim 6, wherein a check valve (CV1) is connected to the intermediate suction portion (35), the check valve (CV1) preventing the refrigerant from flowing in a direction from the compressor (22) toward the thermal storage section (60) in the first utilization heating operation. 5
8. The regenerative air conditioner of claim 7, wherein the intermediate suction pipe (35) includes an inner pipe portion (36) located inside a casing (22a) of the compressor (22), and the check valve (CV1) is located at the inner pipe portion (36). 10
9. The regenerative air conditioner of any one of claims 1-5, wherein the compressor section (22, 80) is configured as a compressor section (80) of a two-stage compression type, the compressor section (80) having a low-stage compressor (81) which compresses a low-pressure refrigerant, and a high-stage compressor (82) which further compresses the refrigerant which has been compressed in the low-stage compressor (81) in the first utilization heating operation, and the intermediate suction portion (35) communicates with a suction pipe (86) of the high-stage compressor (82). 15 20 25
10. The regenerative air conditioner of any one of claims 1-9, wherein the refrigerant circuit (11) includes an intermediate introduction pipe (91) which communicates a liquid line (L1) of the refrigerant circuit (11) with the intermediate suction portion (35) and has a pressure-reducing valve (EV5), and a second heat exchanger (92) which exchanges heat between the refrigerant flowing through the liquid line (L1) after being condensed in the indoor heat exchanger (72) and the refrigerant having a pressure reduced by the pressure-reducing valve (EV5) of the intermediate introduction pipe (91), and in the refrigerant circuit (11) in the first utilization heating operation, the refrigerant which is controlled to be in a wet-vapor state by the pressure-reducing valve (EV5) of the intermediate introduction pipe (91) is mixed with the refrigerant which has been evaporated in the thermal storage section (60), and is taken into the intermediate suction portion (35). 30 35 40 45
11. The regenerative air conditioner of any one of claims 1-10, wherein the control section (60) includes a thermal storage circuit (61) to which a thermal storage tank (62) and a thermal storage heat exchanger (63) are connected and in which the thermal storage medium circulates, the thermal storage tank (62) accumulating the thermal storage medium, and the thermal storage heat exchanger (63) exchanging heat between the refrigerant in the refrigerant circuit (11) and the thermal storage medium. 50 55

FIG. 1

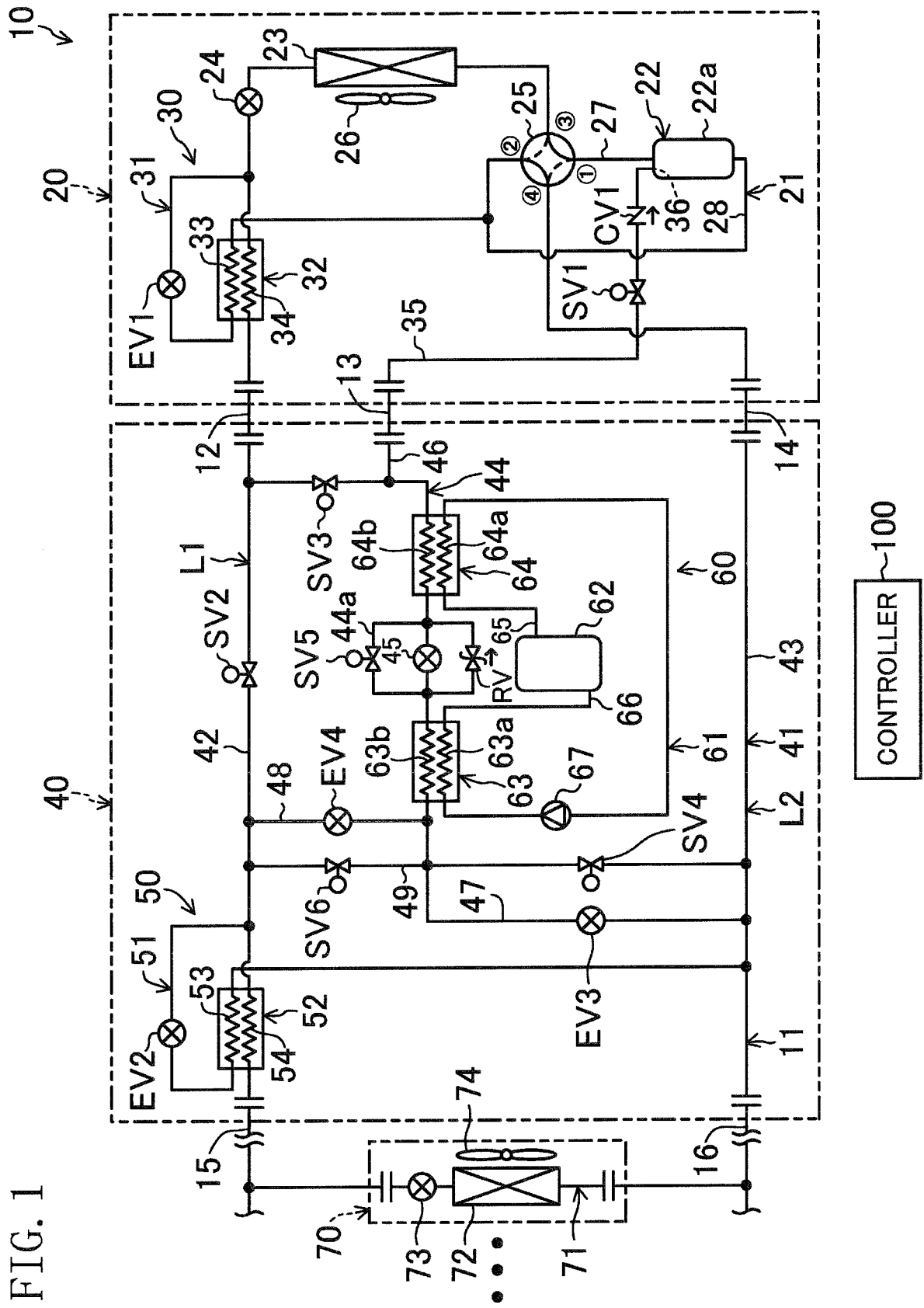


FIG. 2

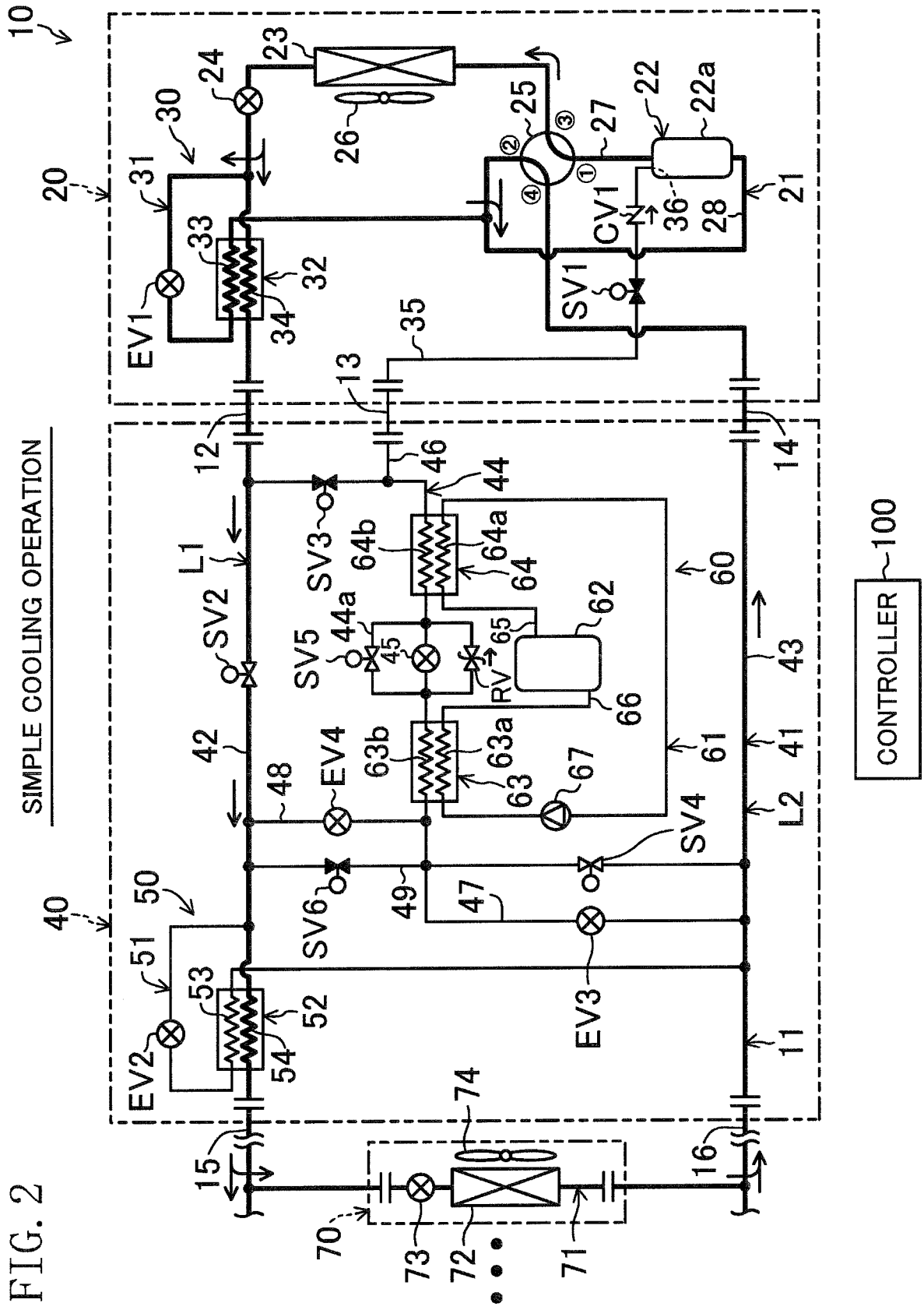


FIG. 3

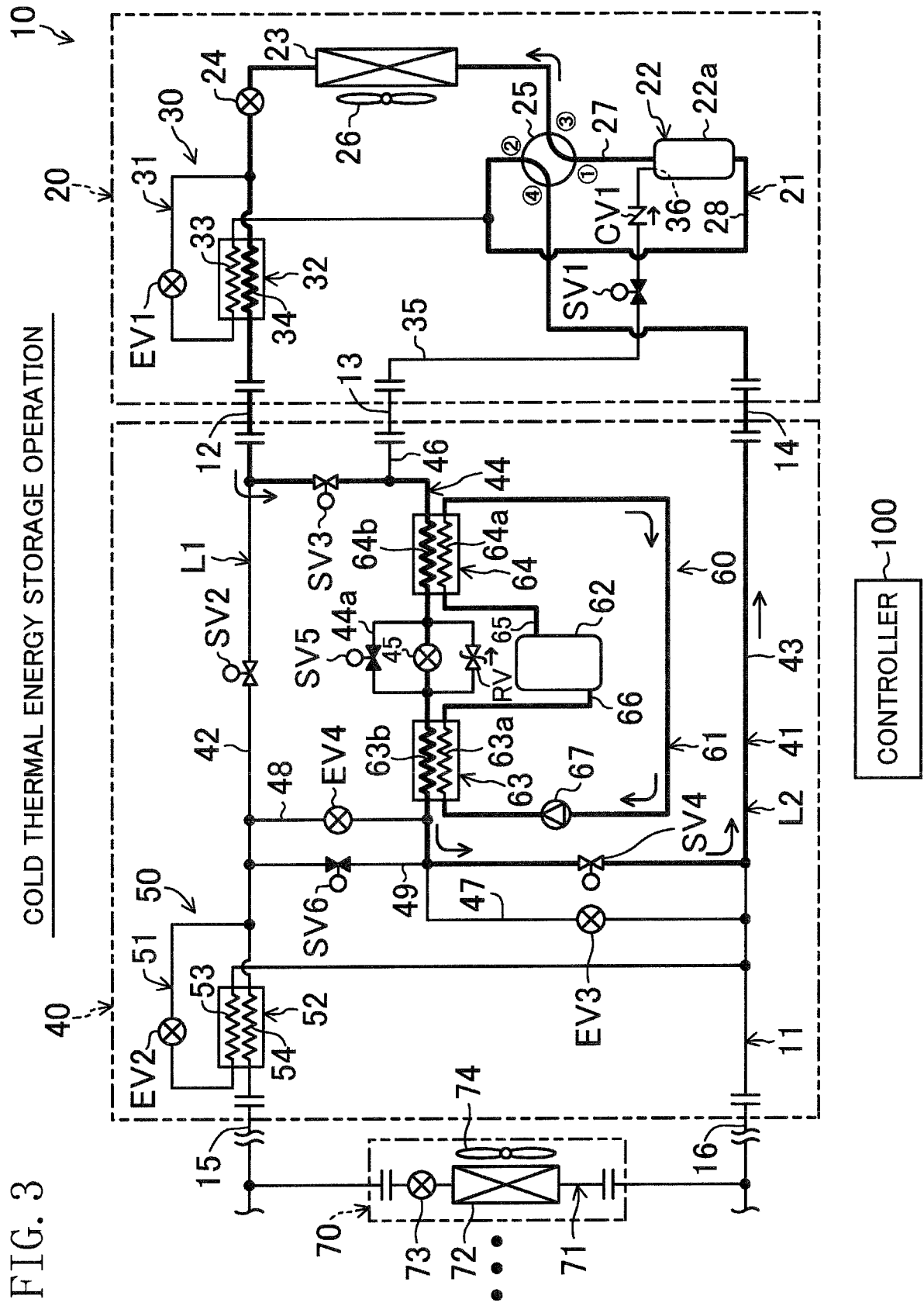
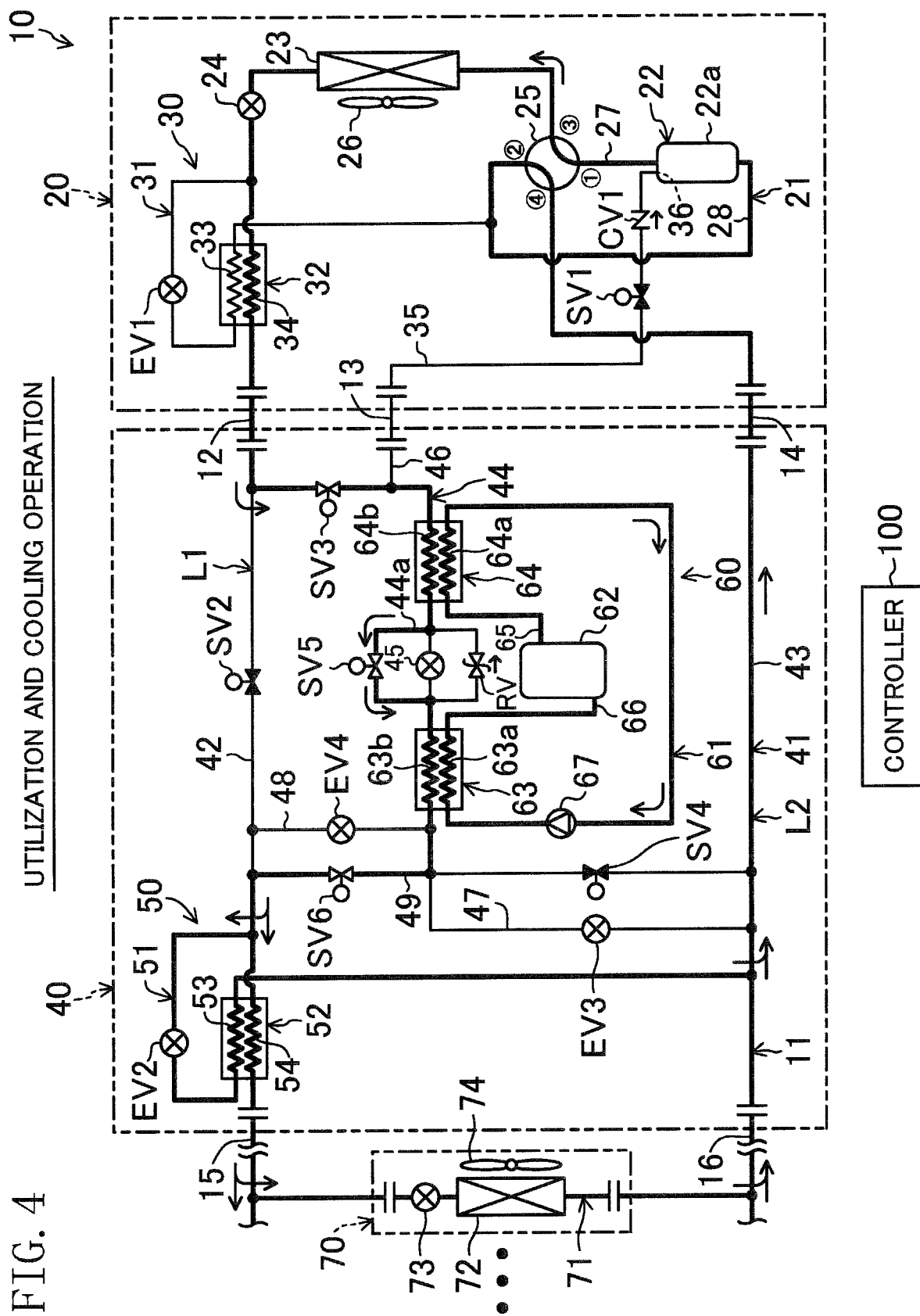


FIG. 4



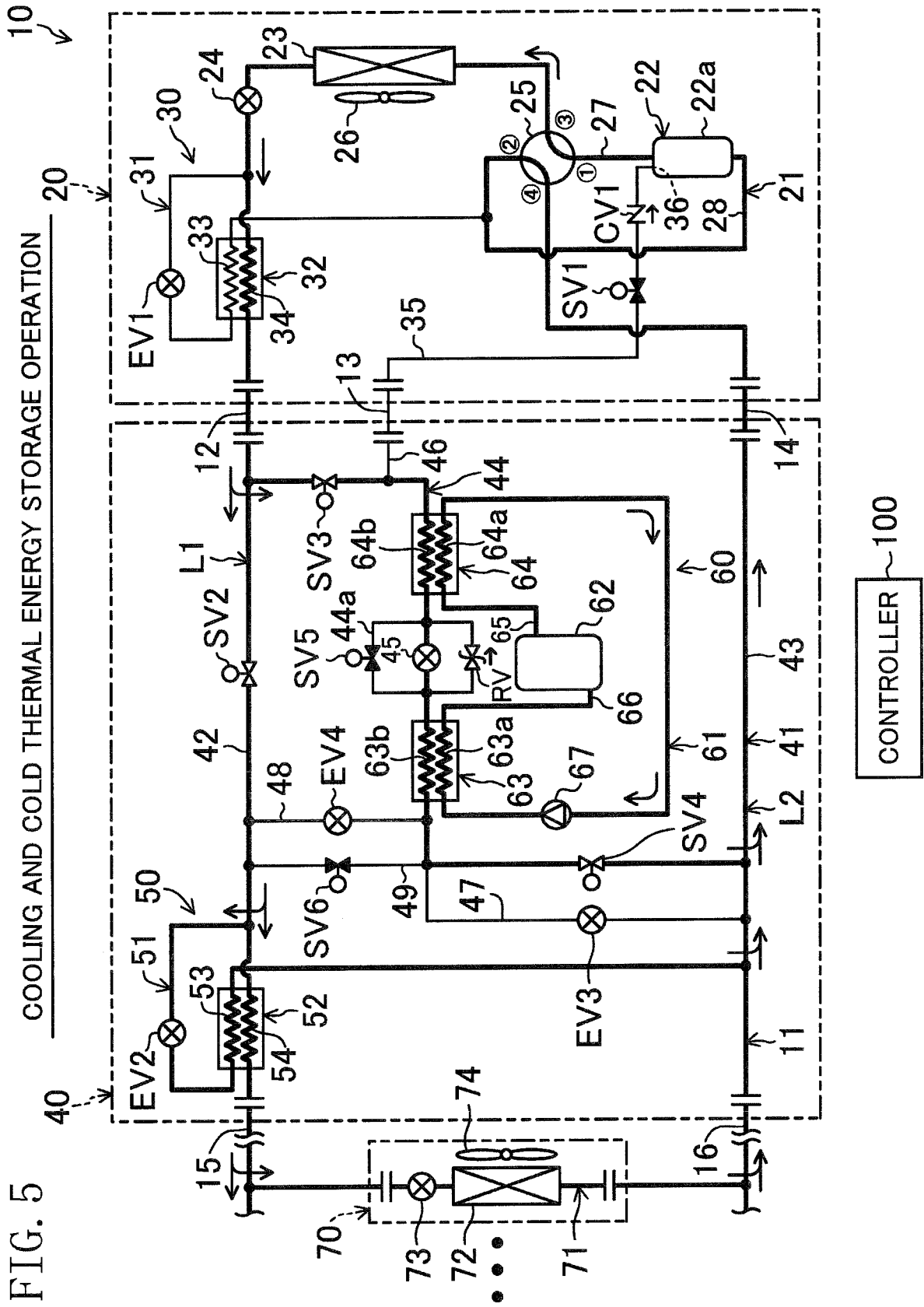


FIG. 6

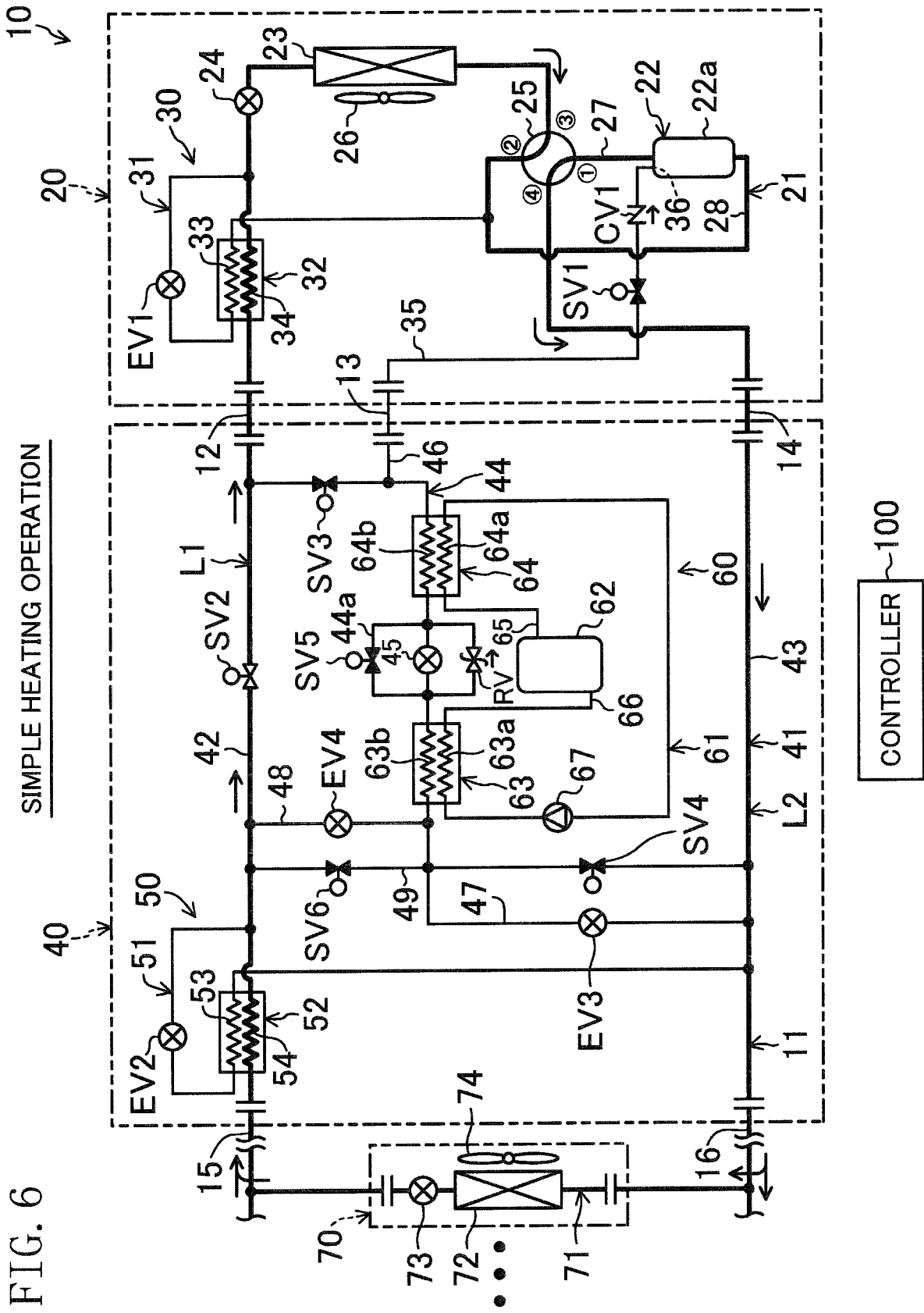


FIG. 7

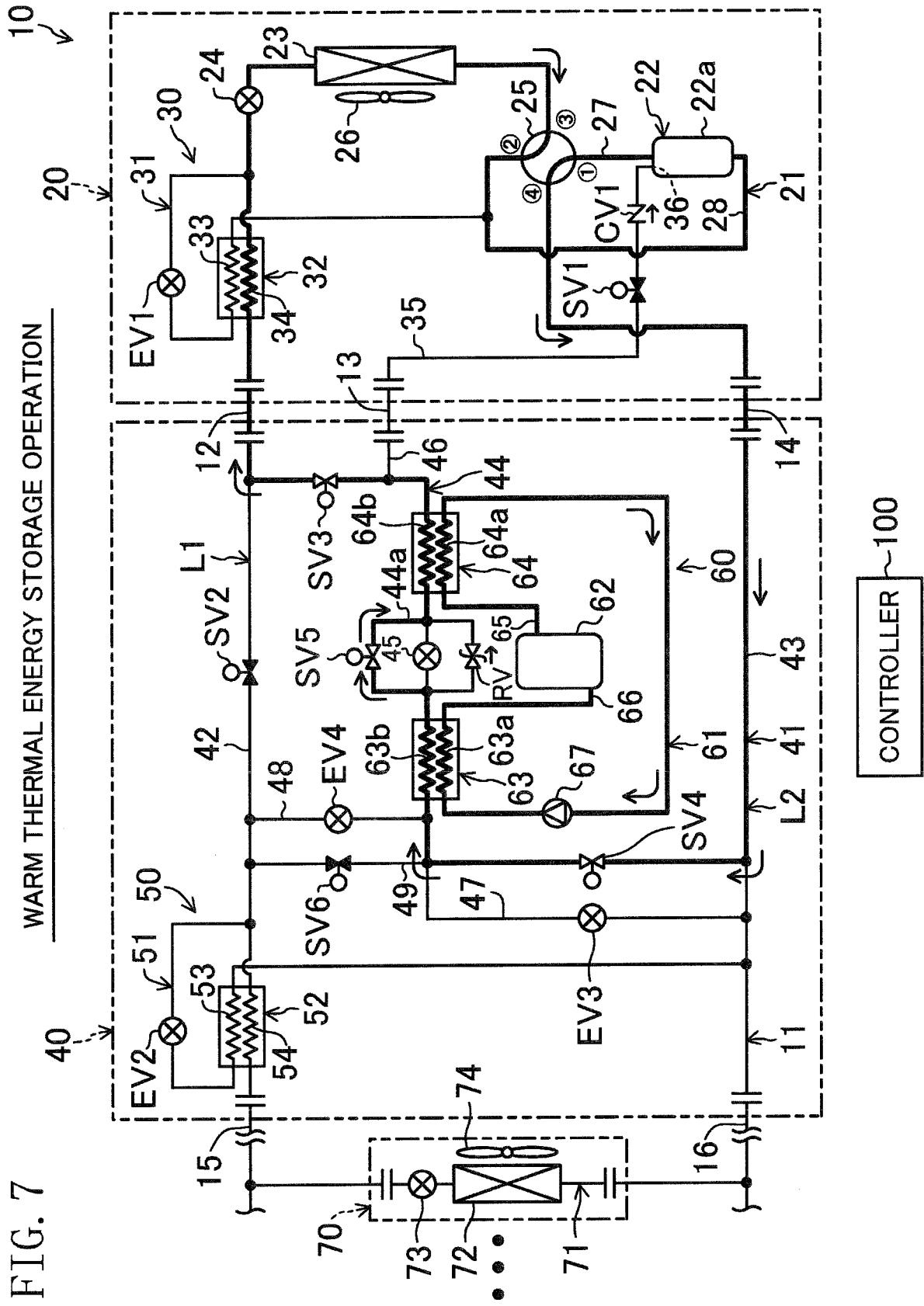
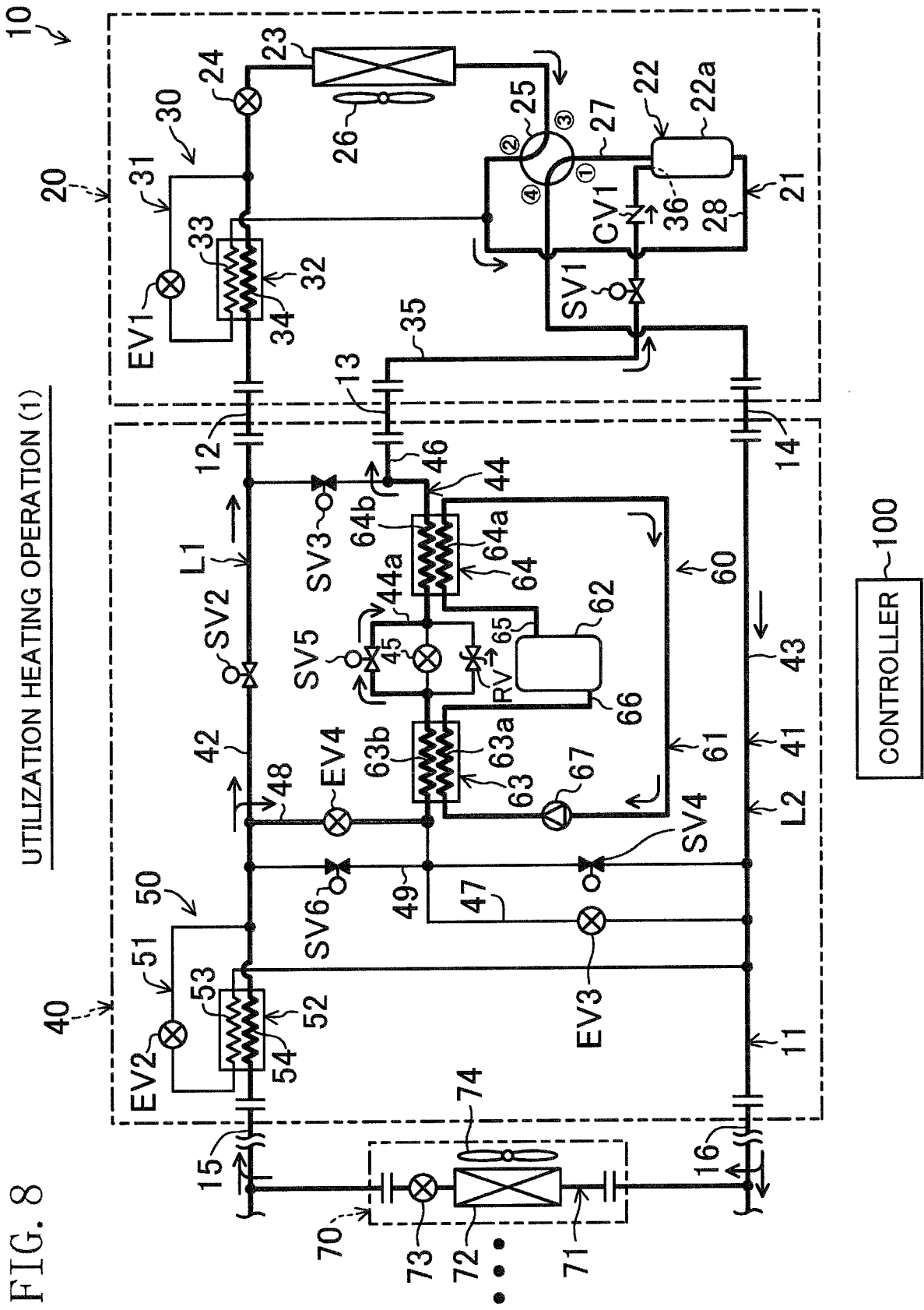
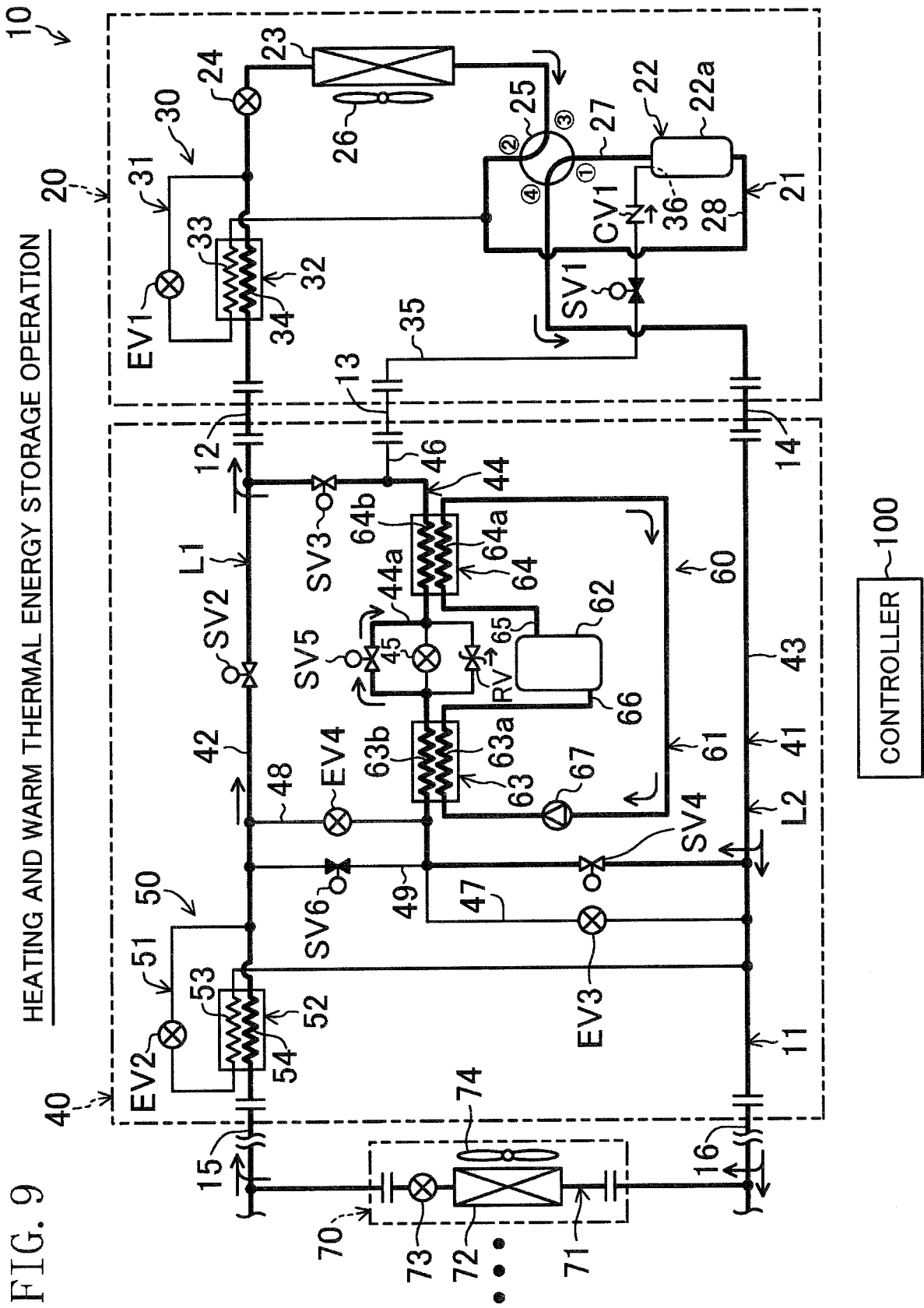
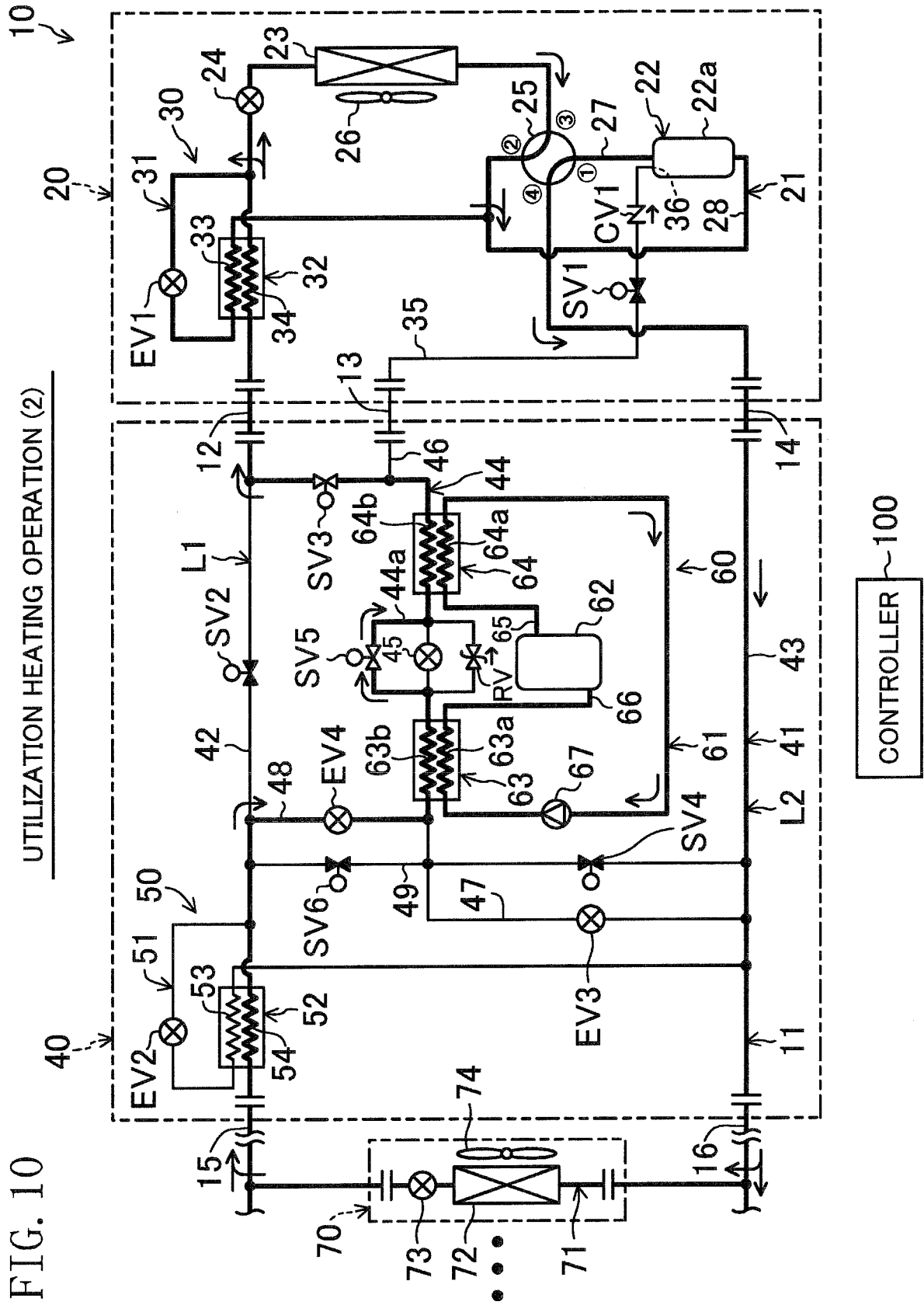


FIG. 8







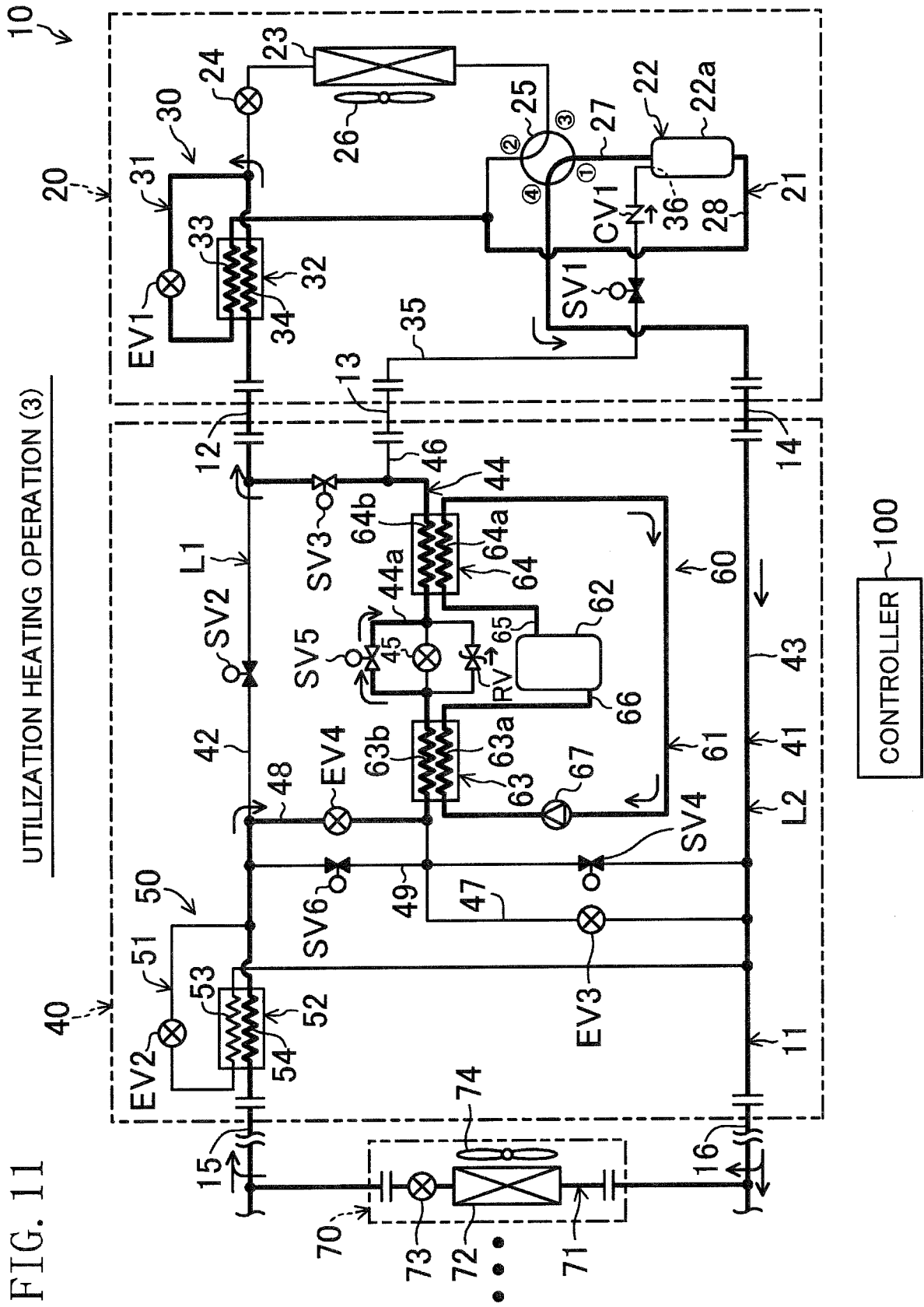


FIG. 12

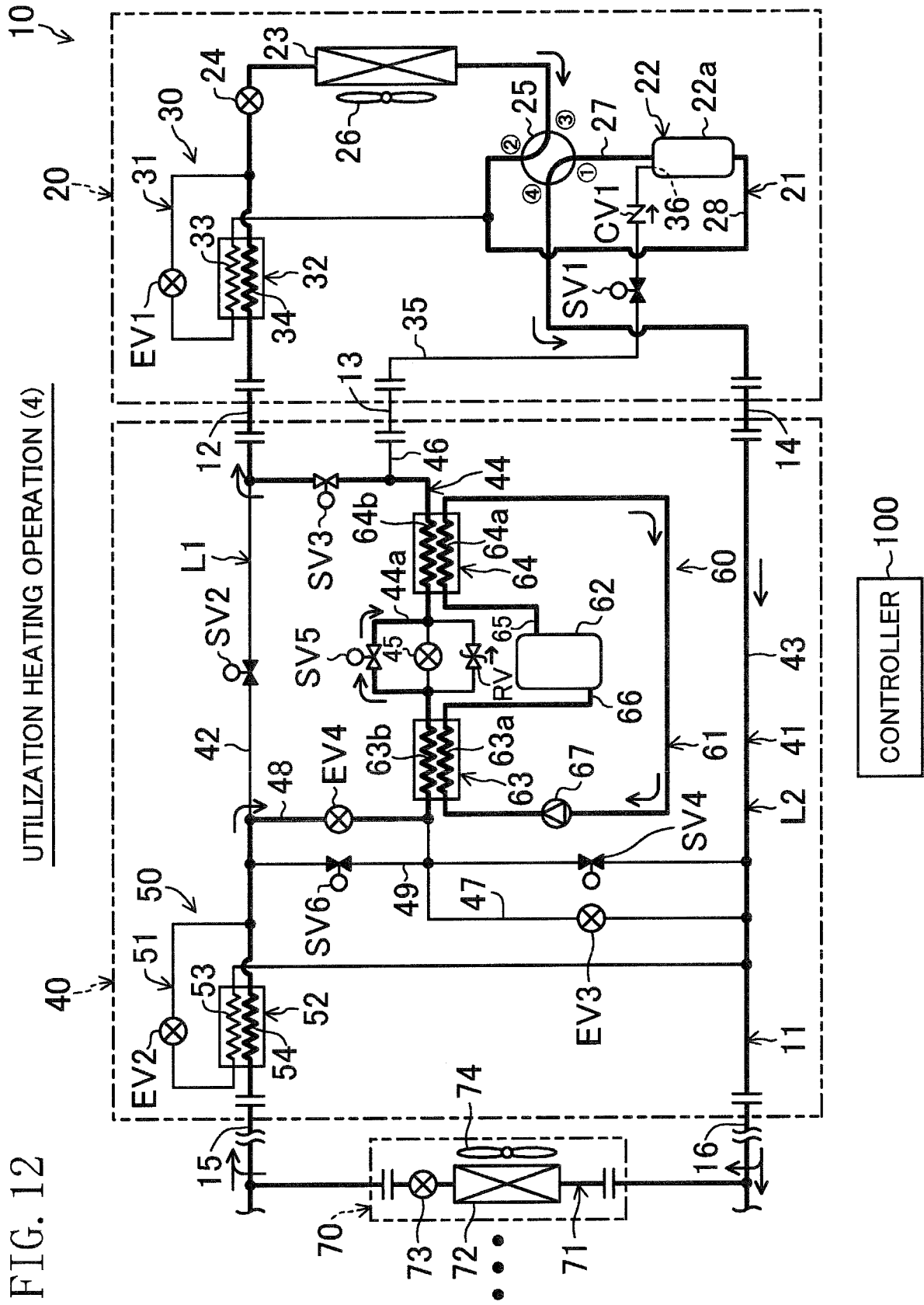


FIG. 13

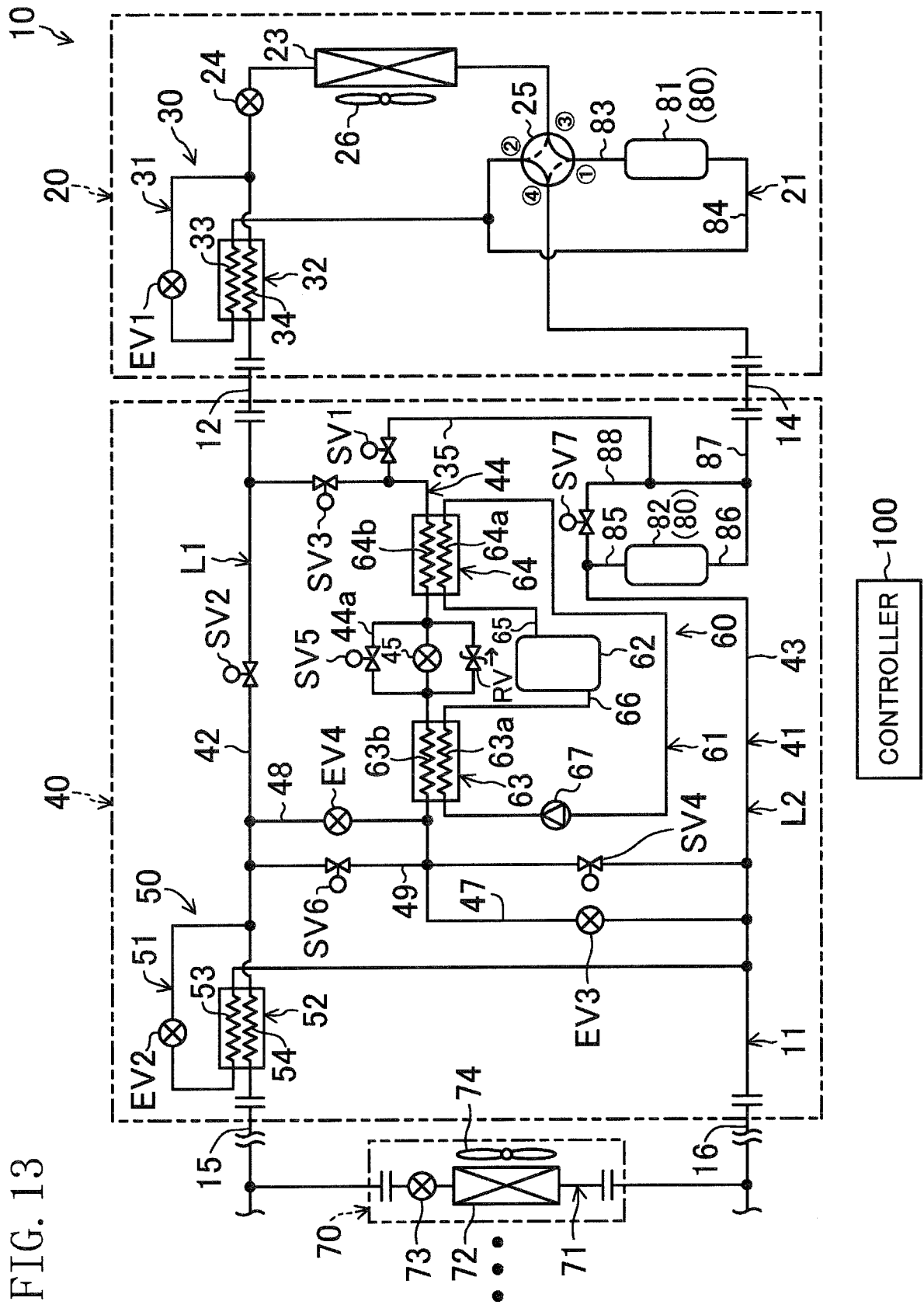


FIG. 14

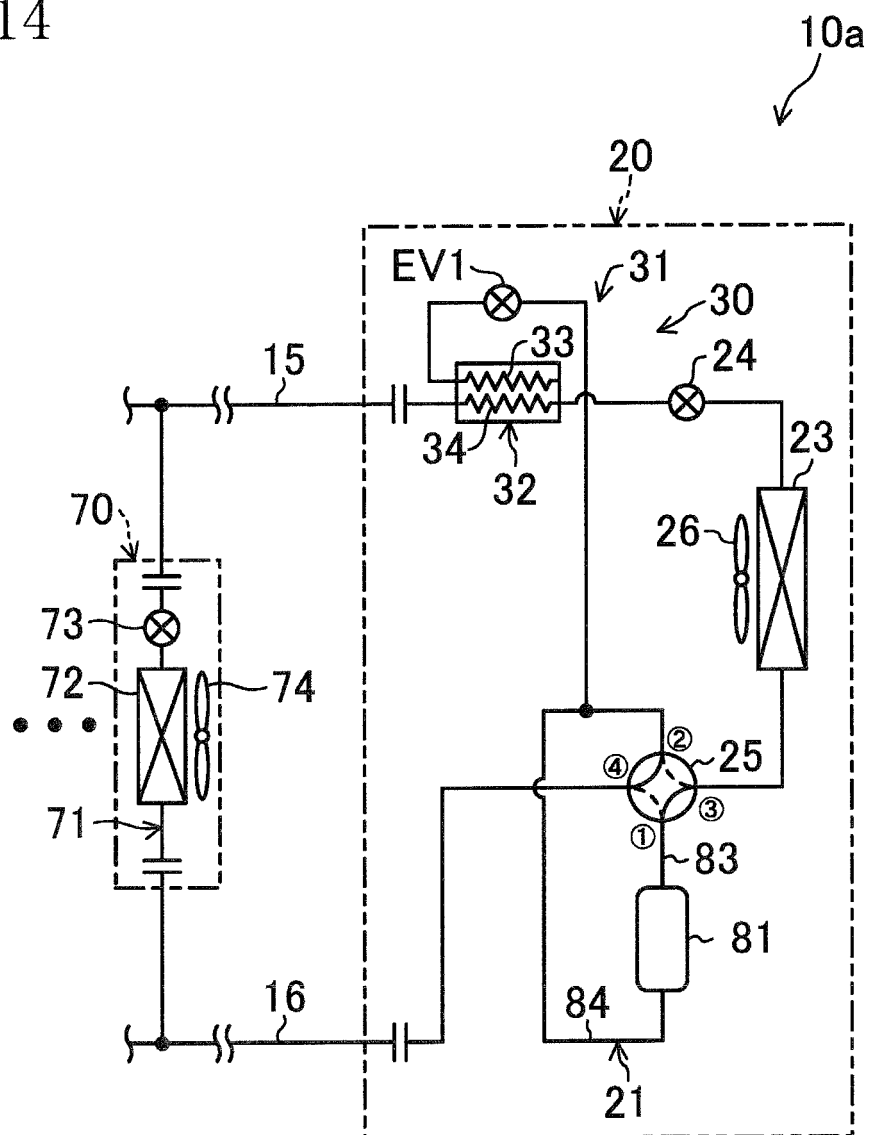


FIG. 15

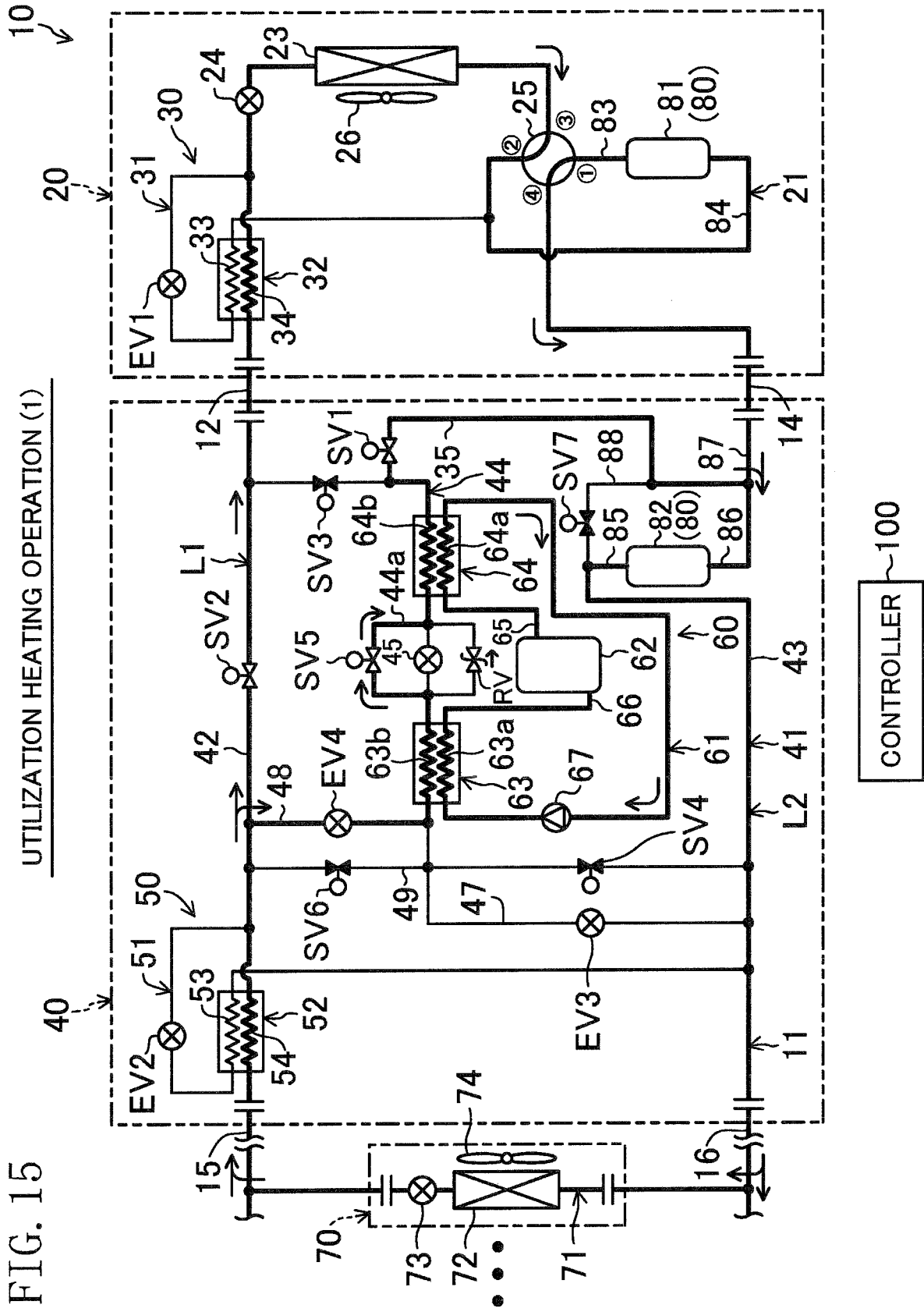


FIG. 16

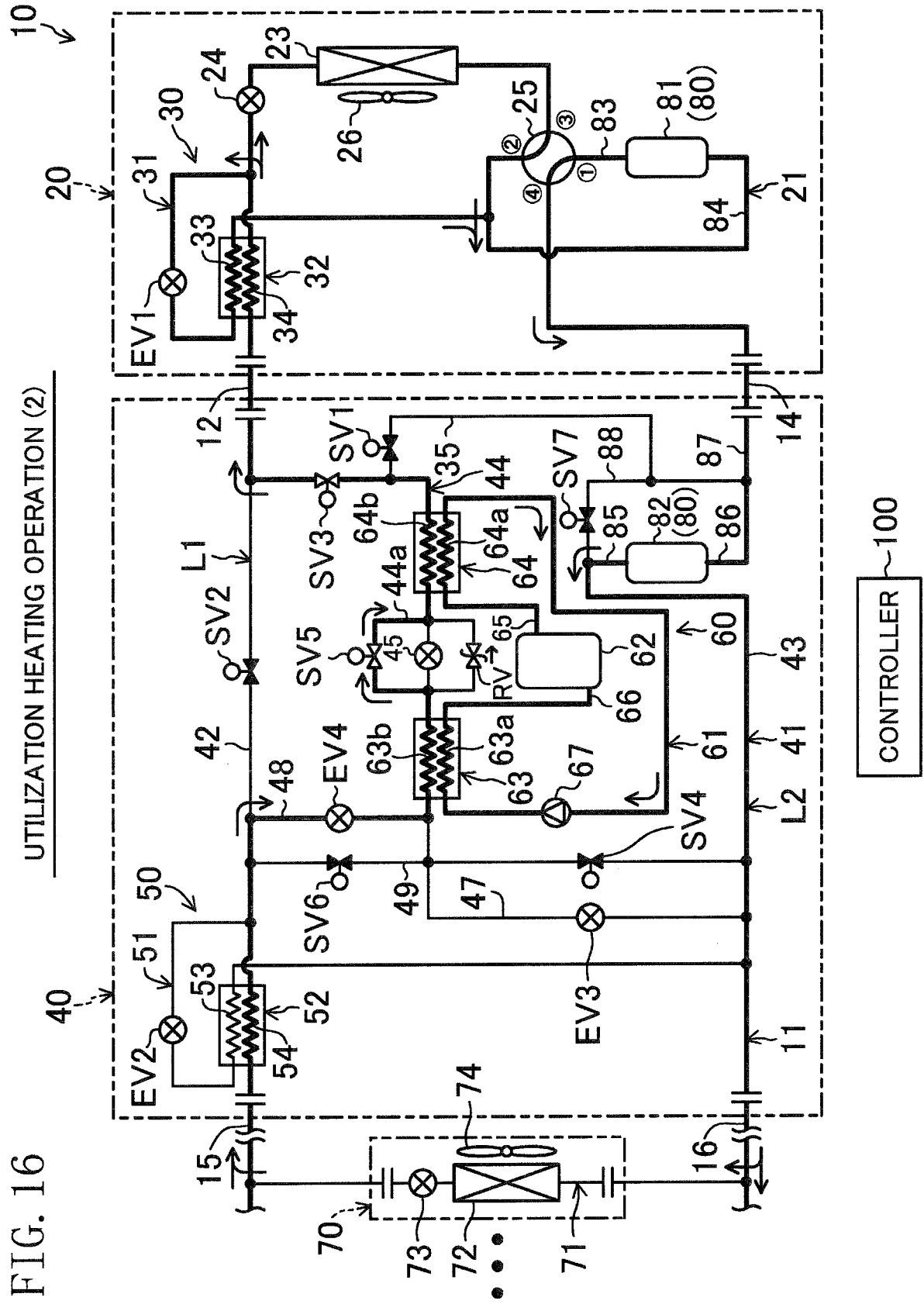
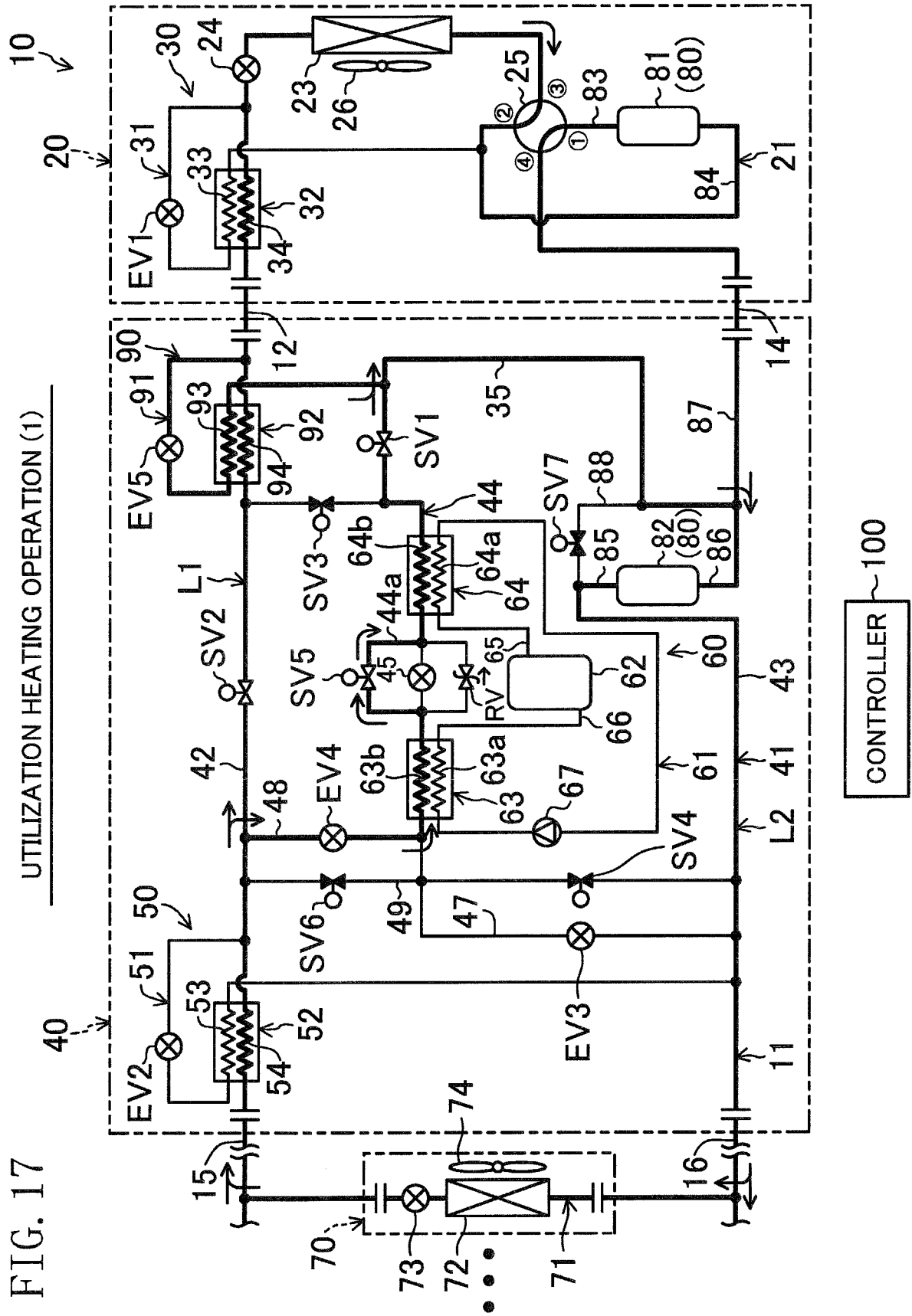


FIG. 17



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/006398

A. CLASSIFICATION OF SUBJECT MATTER

F25B13/00(2006.01)i, F24F5/00(2006.01)i, F25B1/00(2006.01)i, F25B1/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B13/00, F24F5/00, F25B1/00, F25B1/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2006-029738 A (Mitsubishi Electric Corp.), 02 February 2006 (02.02.2006), paragraphs [0043] to [0049]; fig. 10 (Family: none)	1, 6 7-9, 11 2-5, 10
X Y A	JP 01-127871 A (Mitsubishi Electric Corp.), 19 May 1989 (19.05.1989), page 3, lower right column, line 15 to page 6, upper left column, line 11; fig. 2 (Family: none)	1, 6 7-9, 11 2-5, 10
Y	JP 08-313072 A (Daikin Industries, Ltd.), 29 November 1996 (29.11.1996), paragraph [0022]; fig. 1, 4 to 6 (Family: none)	7-8

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search
23 March 2016 (23.03.16)

Date of mailing of the international search report
05 April 2016 (05.04.16)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/006398

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 09-079667 A (Denso Corp.), 28 March 1997 (28.03.1997), paragraphs [0012] to [0014]; fig. 1 (Family: none)	7-8
Y	JP 2014-142158 A (Denso Corp.), 07 August 2014 (07.08.2014), paragraph [0031]; fig. 1 (Family: none)	7-8
Y	JP 2012-180945 A (Mitsubishi Heavy Industries, Ltd.), 20 September 2012 (20.09.2012), paragraph [0026]; fig. 1 (Family: none)	7-9
Y	JP 11-051506 A (Daikin Industries, Ltd.), 26 February 1999 (26.02.1999), claim 1; fig. 32 to 48 (Family: none)	11
Y	JP 2014-126350 A (Daikin Industries, Ltd.), 07 July 2014 (07.07.2014), claims; fig. 1 to 7 (Family: none)	11
Y	JP 2014-126348 A (Daikin Industries, Ltd.), 07 July 2014 (07.07.2014), claims; fig. 1 to 8 (Family: none)	11
A	JP 2007-010288 A (JFE Engineering Corp.), 18 January 2007 (18.01.2007), entire text; all drawings (Family: none)	1-11
A	JP 2013-092342 A (Daikin Industries, Ltd.), 16 May 2013 (16.05.2013), entire text; all drawings (Family: none)	1-11

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007017089 A [0003]