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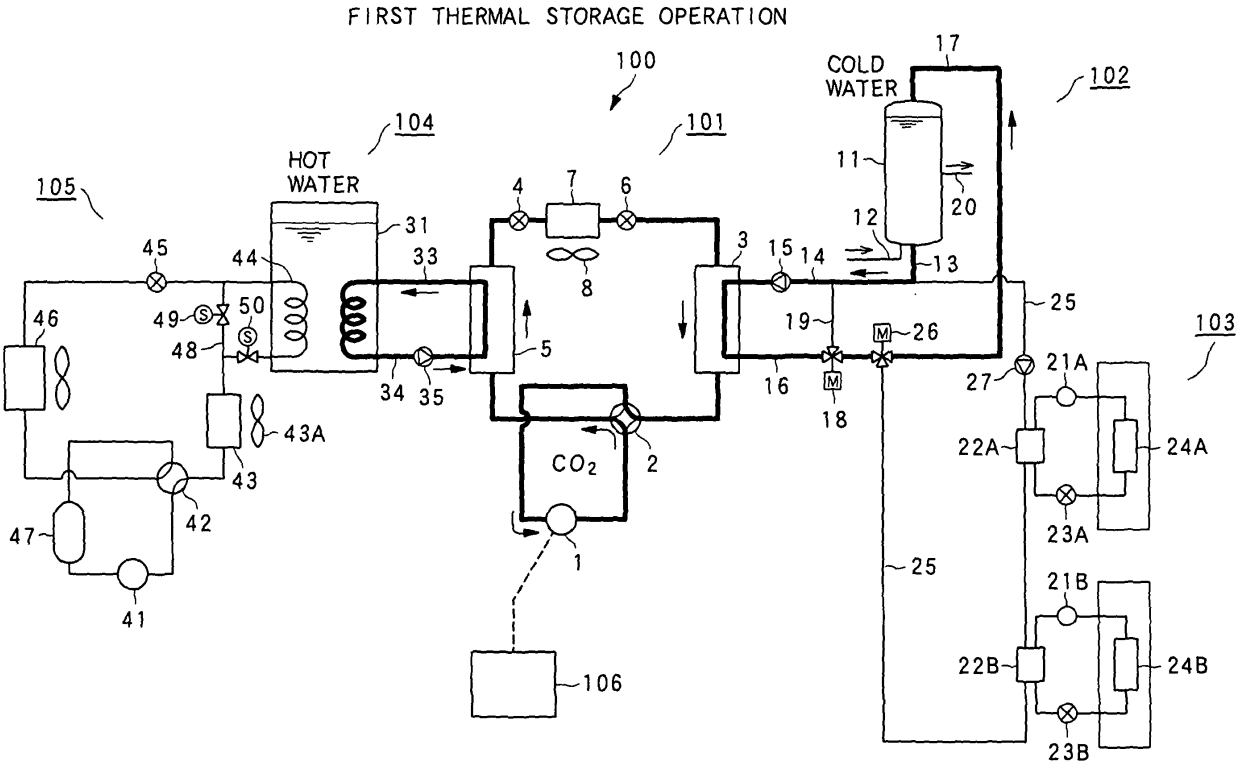
## (54) Refrigeration system

(57) A refrigeration system including a refrigerating cycle for heat source that is operated with nighttime power and generates cold water and hot water, first and second cold/hot water thermal storage device for individually stocking hot water or cold water generated in the refrigerating cycle for heat source, a hot water supply device using the hot water stocked in the first cold/hot water thermal storage device, and an air conditioner using the cold water stocked in the second cold/hot water thermal storage device as a part of a heat source of an air-conditioning refrigerating cycle.

FIG. 1

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## Description

### BACKGROUND OF THE INVENTION

1. Field of the Invention

**[0001]** The present invention relates to a refrigeration system, and particularly to a refrigeration systemhaving a refrigerating cycle for heat source that can be operated with nighttime power.

2. Description of the Related Art

**[0002]** There is generally known a refrigeration system in which a compressor, a condenser, a pressure-reducing device and an evaporator are successively connected through a refrigerant pipe in this order to constitute a refrigerating cycle, cold water is generated by using heat in the evaporator of the refrigerating cycle as a heat source, the heat of the cold water thus generated is thermally stored in an ice thermal storage tank, and cooling operation based on thermal storage can be performed by utilizing the cold-water heat thus thermally stored under cooling operation (see JP-A-2002-130770).

**[0003]** In the conventional refrigeration systemas described above, the heat generated in the condenser is discharged to the outside during the thermal storage operation under which heat is thermally stored in the ice thermal storage tank, and thus the heat concerned is not effectively used.

**[0004]** Not applied to only the above technique, heat pump type hot water supply equipment also generates hot water by using as a heat source the heat generated in a condenser in a refrigerating cycle, and stores the heat of the hot water thus generated in a hot-water stocking tank. In this case, the heat of the condenser is also discharged to the outside during the hot-water stocking operation, and thus the heat concerned is not effectively used.

### SUMMARY OF THE INVENTION

**[0005]** Therefore, the present invention has been implemented to solve the above problem of the related art, and has an object to provide a refrigeration system in which heat loss can be suppressed during the thermal storage operation.

**[0006]** In order to attain the above object, according to a first aspect of the present invention, there is provided a refrigeration system comprising: a refrigerating cycle for heat source that is operated with nighttime power and generates cold water and hot water; first and second cold/hot water thermal storage device for individually stocking hot water or cold water generated in the refrigerating cycle for heat source; a hot water supply device using the hot water stocked in the first cold/hot water thermal storage device; and an air conditioner using the cold water stocked in the second cold/hot water thermal storage device as a part of a heat source of an air-conditioning refrigerating cycle.

**[0007]** According to a second aspect of the present invention, there is provided a refrigerating system comprising: a refrigerating cycle for heat source including a first compressor, a first four-way valve, a first heat exchanger, a first pressure-reducing device and a second heat exchanger that are successively connected through a refrigerant pipe in this order, the first four-way valve being switched so that the first heat exchanger acts as one of a heat-radiating heat source and a heat-absorbing heat source while the second heat exchanger acts as the other heat source; a first cold/hot water thermal storage device that is connected to the first heat exchanger through a water pipe and stocks hot water when the first heat exchanger acts as the heat-radiating heat source or stocks cold water when the first heat exchanger acts as the heat-absorbing heat source; a refrigerating machine that is connected to the first cold/hot water thermal storage device and enables supercooling operation using cold water when the cold water is stocked in the first cold/hot water thermal storage device; a second cold/hot water thermal storage device that is connected to the second heat exchanger through a water pipe and stocks hot water when the second heat exchanger acts as the heat-radiating heat source or stocks cold water when the second heat exchanger acts as the heat-absorbing heat source; and an air-conditioning refrigerating cycle that is connected to the second cold/hot water thermal storage device and enables supercooling operation or refrigerant heating operation using the cold/hot water stocked in the second cold/hot water thermal storage device.

**[0008]** In the above refrigerating system, the air-conditioning refrigerating cycle comprises a second compressor, a second four-way valve, a third heat exchanger, a fourth heat exchanger for heat-exchanging with the cold/hot water in the second cold/hot water thermal storage device, a second pressure-reducing device and a fifth heat exchanger for heat-exchanging with air in a room to be air conditioned that are connected through a refrigerant pipe in this order.

**[0009]** In the above refrigerating system, the air-conditioning refrigerating cycle has a bypass circuit through which refrigerant bypasses the fourth heat exchanger.

**[0010]** In the above refrigerating system, the refrigerating machine comprises a third compressor, a condenser for heat-exchanging with the cold/hot water in the first cold/hot water thermal storage device, a third pressure-reducing device and an evaporator that are connected through a refrigerant pipe in this order.

**[0011]** In the above refrigerating system, the refrigerating cycle for heat source is equipped with an air heat source type sixth heat exchanger between the first heat exchanger and the first pressure-reducing device.

**[0012]** The above refrigerating system further comprises a controller for operating the refrigerating cycle for heat source with nighttime power.

**[0013]** In the above refrigerating system, refrigerant

with which a high-pressure side is set to supercritical pressure is filled in the refrigerating cycle for heat source.

**[0014]** According to the present invention, the first cold/hot water thermal storage device and the second cold/hot water thermal storage device which can individually stock therein cold/hot water generated in the refrigerating cycle for heat source. Therefore, when the refrigerating cycle for heat source is operated, both the evaporator and the condenser can be effectively used to generate cold water and hot water, and thus the heat loss under the thermal storage operation can be suppressed.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0015]**

Fig. 1 is a refrigerant circuit diagram showing an embodiment of a refrigeration system according to the present invention;

Fig. 2 is a refrigerant circuit diagram showing the embodiment of the refrigeration system according to the present invention;

Fig. 3 is a refrigerant circuit diagram showing the embodiment of the refrigeration system according to the present invention;

Fig. 4 is a refrigerant circuit diagram showing the embodiment of the refrigeration system according to the present invention; and

Fig. 5 is a pressure-enthalpy chart.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0016]** A preferred embodiment according to the present invention will be described with reference to the accompanying drawings.

**[0017]** Fig. 1 is a diagram showing a refrigerant circuit according to an embodiment of the present invention.

**[0018]** A refrigeration system (refrigeration facilities) 100 mainly comprises a refrigerating cycle 101 for heat source which is operated with nighttime power, a first cold/hot water thermal storage device 102 constituting a so-called hot-water stocking tank, a showcase for a shop or a refrigerating machine 103 such as a large-size refrigerator/freezer 103, a second cold/hot water thermal storage device 104, and an air-conditioning refrigerating cycle 105 for air-conditioning a room to be air-conditioned.

**[0019]** The refrigerating cycle 101 for heat source is constructed by successively connecting a first compressor 1, a first four-way valve 2, a first heat exchanger 3, a first pressure-reducing device 4 and a second heat exchanger 5 through a refrigerant pipe in this order, and also connecting an auxiliary pressure-reducing device 6 and an air heat source type sixth heat exchanger 7 in series between the first heat exchanger 3 and the first pressure-reducing device 4. Reference numeral 8 represents an air blower.

**[0020]** According to the refrigerating cycle 101 for heat source, by properly switching the first four-way valve 2, the first heat exchanger 3 acts as a heat-radiating heat source or heat-absorbing heat source, and at the same time the second heat exchanger 5 acts as a heat-absorbing heat source or a heat-radiating heat source.

**[0021]** The first cold/hot water thermal storage device 102 is constructed to contain a hot-water tank 11. A supply pipe 12 for supplying city water to the hot-water tank 11 and a feed pipe 13 for circulating the water of the hot-water tank 11 to the first heat exchanger 3 are connected to the bottom portion of the hot-water tank 11. An outgoing pipe 14 is connected to the feed pipe 13, and the first heat exchanger 3 is connected to the outgoing pipe 14 through a pump 15. An incoming pipe 16 is connected to the first heat exchanger 3, and further connected to the upper portion of the hot-water stocking tank 11 through a return pipe 17.

**[0022]** A hot-water supply pipe 20 is connected to some midpoint of the hot-water stocking tank 11, and a hot-water supply device such as a bath, a hot water supplier or the like (not shown) is connected to the hot-water supply pipe 20. An electrically-operated three-way valve 18 is connected to the incoming pipe 16, and a so-called short cycle pipe 19 is connected between the three-way valve 18 and the upstream point of the pump 15.

**[0023]** The first cold/hot water thermal storage device 102 is connected to the showcase for the shop or the refrigerating machine 103 such as a large-size refrigerator/freezer or the like, and when cold water is stocked in the first cold/hot water thermal storage device 102, the refrigerating machine 103 is designed so that supercooling operation using the cold water concerned can be performed by the refrigerating machine 103 as described later.

**[0024]** In this construction, two refrigerating machines 103 are connected to the first cold/hot water thermal storage device 102, and each of the refrigerating machines 103 is constructed by connecting a third compressor 21A, 21B, a condenser 22A, 22B for carrying out heat-exchange with cold/hot water of the hot-water stocking tank 11, a third pressure-reducing device 23A, 23B and an evaporator 24A, 24B through a refrigerant pipe in this order. Each condenser 22A, 22B is connected to a water pipe 25 in series, and the water pipe 25 is connected to the feed pipe 13. The water pipe 25 is connected between the feed pipe 13 and an electrically-operated three-way valve 26, and the three-way valve 26 is connected to the return pipe 17 between the other three-way valve 18 and the hot-water stocking tank 11. Reference numeral 27 represents a pump.

**[0025]** The second cold/hot water thermal storage device 104 is equipped with a thermal storage tank 31, and water pipes 33 and 34 for circulating water or brine are connected between the thermal storage tank 31 and the second heat exchanger 5, and a pump 35 is connected to the water pipe 34. When the second heat exchanger 5 acts as a heat-radiating heat source, hot water is

stocked in the thermal storage tank 31, and when the second heat exchanger 5 acts as a heat-absorbing heat source, cold water (in this case, ice) is stocked in the thermal storage tank 31.

**[0026]** The air-conditioning refrigerating cycle 105 is constructed by successively connecting a second compressor 41, a second four-way valve 42, a third heat exchanger 43, a fourth heat exchanger 44 for heat-exchanging with cold/hot water of the thermal storage tank 31, a second pressure-reducing device 45, a fifth heat exchanger 46 for heat-exchanging with indoor air in the room to be air-conditioned and an accumulator 47 in this order. Furthermore, a bypass circuit 48 through which the refrigerant bypasses the fourth heat exchanger 44 is provided, and an opening and closing valve 49 is connected to the bypass circuit 48. Reference numeral 50 represents an opening and closing valve, and reference numeral 43A represents an air blower.

**[0027]** According to the refrigerating cycle 105, it is possible to carry out supercooling operation or refrigerating heating operation which uses hot water, cold water and/or ice. In the above construction, any one of hot water and cold water is stocked in the hot-water stocking tank 11, and any one of hot water and ice (cold water) is stocked in the thermal storage tank 31.

**[0028]** In the above construction, refrigerant with which the high pressure side is set to supercritical pressure under operation, for example, carbon dioxide ($CO_2$) is filled in the refrigerating cycle 101 for heat source. In a case where $CO_2$ refrigerant is filled, the inside of the high-pressure circuit is operated under supercritical pressure during operation as shown in a pressure-enthalpy chart of Fig. 5 in accordance with a specific condition such as a case where the outside air temperature increases to 30°C or more in summer season or a load is increased. Not only $CO_2$ refrigerant, but also ethylene, diborane, ethane, nitrogen oxide or the like may be used as refrigerant with which the inside of the high pressure circuit is operated under supercritical pressure.

**[0029]** In Fig. 5, the state of the refrigerant at the outlet of the compressor 1 is represented by "a". The refrigerant is passed through the heat exchanger 3 and circulated, and cooled till the state a of the refrigerant is shifted to a state b while he heat of the refrigerant is radiated to water. The refrigerant is cooled till the state b is shifted to a state c as occasion demands. Subsequently, the refrigerant is reduced in pressure in the pressure-reducing device 4 so that the state of the refrigerant reaches a state d. Under the state d, two-phase mixture of gas/liquid refrigerant is formed. In the heat exchanger 5, the liquid-phase refrigerant of the gas/liquid refrigerant is evaporated while absorbing heat. A state e is an intermediate state of the heat exchanger 5, and the gas-phase refrigerant of the gas/liquid refrigerant is heated till the state of the refrigerant is shifted to a state f and then fed to the suction pipe of the compressor 1.

**[0030]** In this construction, the high-pressure single-phase gas refrigerant discharged from the compressor 1 is not condensed, but reduced in temperature in the heat exchanger 3, so that the refrigerant is cooled till the state thereof is shifted to the state c under which the temperature of the refrigerant is lower than the temperature of water by several degrees. As a result, the water temperature is increased to about 80°C or more.

**[0031]** Furthermore, the above construction is provided with a controller 106 for controlling the operation of the first compressor 1 in the refrigerating cycle 101 for heat source, and the controller 106 drives the first compressor 1 in only an operating time zone for nighttime power (for example, 8:00PM - 6:00AM) in which the power consumption charge is generally set to a low value.

**[0032]** Next, the operation of this embodiment will be described.

A. First Thermal Storage Operation

**[0033]** This thermal storage operation is an operation of stocking hot-water heat in the thermal storage tank 31 and also stocking cold-water heat in the hot-water stocking tank 11 as shown in Fig. 1, and it is carried out by driving the first compressor 1 of the refrigerating cycle 101 for heat source with nighttime power. During this operation, in the refrigerating cycle 101 for heat source, the refrigerant discharged from the first compressor 1 is circulated through the first four-way valve 2, the second heat exchanger 5, the first pressure-reducing device 4 and the first heat exchanger 3, and then it is further passed through the first four-way valve 2 and returned to the first compressor 1 as indicated by a heavy line in Fig. 1. The auxiliary pressure-reducing device 6 is fully opened, and the air blower 8 is stopped. In the second heat exchanger 5, heat is radiated and hot water is generated by utilizing the heat thus radiated. That is, in the second cold/hot water thermal storage device 104, the pump 35 is driven, and water or brine is circulated through the water pipes 33, 34 between the second heat exchanger 5 and the thermal storage tank 31, so that the hot-water heat is stocked in the thermal storage tank 31. Furthermore, in the first heat exchanger 3, heat is absorbed and cold water is generated by utilizing the heat absorption concerned. In this case, in the cold/hot water thermal storage device 102, the pump 15 is driven, and city water in the hot-water stocking tank 11 is circulated through the water pipes 3, 14, 16, 17 between the first heat exchanger 3 and the hot-water stocking tank 11, so that cold-water heat is stocked in the hot water stocking tank 11.

**[0034]** If the thermal storage into the thermal storage tank 31 is not required in the above operation, the air heat source type sixth heat exchanger 7 is functioned in place of the second heat exchanger 5. Furthermore, if the thermal storage into the hot water stocking tank 11 is not required, the driving of the pump 15 is stopped, the air blower 8 is driven, and the air heat source type sixth heat exchanger 7 is functioned in place of the first heat exchanger 3.

B. Heating Operation using Hot Water

**[0035]** This heating operation is a heating operation using the hot-water heat of the thermal storage tank 31 as shown in Fig. 2. In this case, in the air-conditioning refrigerating cycle 105, the refrigerant discharged from the second compressor 41 is circulated through the second four-way valve 42, the fifth heat exchanger 46, the second pressure-reducing device 45, the fourth heat exchanger 44 and the third heat exchanger 43, and then it is passed through the four-way valve 42 and then returned to the second compressor 41 as indicated by a heavy line. Under this state, the refrigerant is heated with hot water in the fourth heat exchanger 44 and thus the heating efficiency is more enhanced as compared with general air conditioners.

**[0036]** Furthermore, it is possible to carry out an effective defrosting operation of the third heat exchanger 43 at a low outside air temperature by using this hot-water heat, and the continuous operation of the air-conditioning refrigerating cycle 105 concerned can be performed.

**[0037]** When no hot water exists in the thermal storage tank 31, the opening and closing valve 50 is closed while the opening and closing valve 49 is opened. Under this state, the refrigerant bypasses the fourth heat exchanger 44, and it is passed through the bypass pipe 48 and then circulated through the third heat exchanger 43.

C. Refrigerating Operation using Cold Water

**[0038]** As indicated by a heavy line of Fig. 2, this refrigerating operation is an operation using the cold-water heat of the hot-water stocking tank 11 during the operation of the refrigerating machine 103. During this refrigerating operation, in the refrigerating machine 103, the refrigerant discharged from the third compressors 21A, 21B is circulated through the condensers 22A, 22B, the third pressure-reducing devices 23A, 23B and the evaporators 24A, 24B, and then returned to the third compressors 21A, 21B. In this case, the pump 27 is driven, and the cold water in the hot-water stocking tank 11 is circulated through the condensers 22A, 22B, passed through the three-way valve 26 and then returned to the hot-water stocking tank 11. In this operation, the refrigerant in the refrigerating machine 103 side is supercooled by the cold water circulated through the condensers 22A, 22B, so that the refrigerating efficiency of the refrigerating machine 103 is enhanced. Accordingly, the daytime power peak in summer season in which the power consumption amount is increased can be reduced.

D. Second Thermal Storage Operation

**[0039]** As shown in Fig. 3, this thermal storage operation is an operation of stocking cold-water heat (ice) in the thermal storage tank 31 and also stocking hot-water heat in the hot-water heat stocking tank 11, and it is carried out by driving the first compressor 1 of the refrigerating cycle 101 for heat source with nighttime power. Under this operation, the refrigerant discharged from the first compressor 1 is first circulated through the first four-way valve 2, the first heat exchanger 3, the first pressure-reducing device 4 and the second heat exchanger 5 in the refrigerating cycle 101 for heat source, and then it is passed through the first four-way valve 2 and returned to the first compressor 1 as indicated by a heavy line in Fig. 3. The auxiliary pressure-reducing device 6 is fully opened, and the air blower 8 is stopped. In the first heat exchanger 3, heat is radiated, and hot water is generated by using the radiated heat. That is, in the first cold/hot water thermal storage device 102, the pump 15 is driven, city water in the hot-water stocking tank 11 is circulated through the water pipes 3, 14, 16, 17 between the first heat exchanger 3 and the hot-water stocking tank 11, and the hot-water heat is stocked in the hot-water stocking tank 11. Furthermore, in the second heat exchanger 5, heat is absorbed, and cold water is generated by using this absorbed heat. In this case, in the second cold/hot water thermal storage device 104, the pump 35 is driven, and water or brine is circulated through the water pipes 33, 34 between the second the exchanger 5 and the thermal storage tank 31 and the cold-water heat (ice) is stocked in the thermal storage tank 31.

**[0040]** In this operation, if the thermal storage into the thermal storage tank 31 is not required, the operation of the pump 35 is stopped, the air blower is operated and the air heat source type sixth heat exchanger 7 is functioned in place of the second heat exchanger 5. As a result, the hot water can be stored in the hot-water stocking tank 11 by using the air heat source. Furthermore, if the thermal storage into the hot-water stocking tank 11 is not required, the operation of the pump 15 is stopped, the air blower 8 is operated and the air heat source type sixth heat exchanger 7 is functioned in place of the first heat exchanger 3.

E. Cooling Operation Using Cold Water (Ice)

**[0041]** As shown in Fig. 4, this cooling operation is an operation using cold-water heat (ice) of the thermal storage tank 31. In this case, in the air-conditioning refrigerating cycle 105, the refrigerant discharged from the second compressor 41 is circulated through the second four-way valve 42, the third heat exchanger 43, the fourth heat exchanger 44, the second pressure-reducing device 45 and the fifth heat exchanger 46, and thereafter it is passed through the second four-way valve 42 and the accumulator 47 and then returned to the second compressor 41 as indicated by a heavy line in Fig. 4. Under this state, the refrigerant is supercooled by the cold water in the fourth heat exchanger 44, and thus the cooling efficiency is more enhanced as compared with general air conditioners.

**[0042]** When no cold water (ice) is thermally stored in the thermal storage tank 31, if the refrigerating system is operated under the state that the opening and closing

valve 50 is closed and the opening and closing valve 49 is opened, the refrigerant bypasses the fourth heat exchanger 44 and passes through the bypass pipe 48 to the second pressure-reducing device 45, so that cooling operation using no cold water (ice) can be performed and thus continuous cooling operation covering the daytime and the nighttime can be performed.

F. Hot Water Supply

**[0043]** As indicated by a heavy line of Fig. 4, the hot-water supply pipe 20 is connected to the hot-water stocking tank 11, and a hot water supplying device such as a bath, a hot water supplier or the like (not shown) is connected to the hot-water supply pipe 20. Accordingly, in this construction, the hot water in the hot water stocking tank 11 can be supplied to the hot water supplying device while the cooling operation using the cold water described above is carried out.

**[0044]** The present invention is not limited to the above embodiment, and various modifications may be made without departing from the subject matter of the present invention. For example, in the above construction, $CO_2$ refrigerant is filled in the refrigerant circuit, however, the refrigerant is not limited to $CO_2$ refrigerant, and Freon-based refrigerant may be filled.

## Claims

**1.** A refrigeration system comprising:

a refrigerating cycle for heat source that is operated with nighttime power and generates cold water and hot water;
first and second cold/hot water thermal storage device for individually stocking hot water or cold water generated in the refrigerating cycle for heat source;
a hot water supply device using the hot water stocked in the first cold/hot water thermal storage device; and
an air conditioner using the cold water stocked in the second cold/hot water thermal storage device as a part of a heat source of an air-conditioning refrigerating cycle.

**2.** A refrigerating system comprising:

a refrigerating cycle for heat source including a first compressor, a first four-way valve, a first heat exchanger, a first pressure-reducing device and a second heat exchanger that are successively connected through a refrigerant pipe in this order, the first four-way valve being switched so that the first heat exchanger acts as one of a heat-radiating heat source and a heat-absorbing heat source while the second heat exchanger acts as the other heat source;
a first cold/hot water thermal storage device that is connected to the first heat exchanger through a water pipe and stocks hot water when the first heat exchanger acts as the heat-radiating heat source or stocks cold water when the first heat exchanger acts as the heat-absorbing heat source;
a refrigerating machine that is connected to the first cold/hot water thermal storage device and enables supercooling operation using cold water when the cold water is stocked in the first cold/hot water thermal storage device;
a second cold/hot water thermal storage device that is connected to the second heat exchanger through a water pipe and stocks hot water when the second heat exchanger acts as the heat-radiating heat source or stocks cold water when the second heat exchanger acts as the heat-absorbing heat source; and
an air-conditioning refrigerating cycle that is connected to the second cold/hot water thermal storage device and enables supercooling operation or refrigerant heating operation using the cold/hot water stocked in the second cold/hot water thermal storage device.

**3.** The refrigerating system according to claim 2, wherein the air-conditioning refrigerating cycle comprises a second compressor, a second four-way valve, a third heat exchanger, a fourth heat exchanger for heat-exchanging with the cold/hot water in the second cold/hot water thermal storage device, a second pressure-reducing device and a fifth heat exchanger for heat-exchanging with air in a room to be air conditioned that are connected through a refrigerant pipe in this order.

**4.** The refrigerating system according to claim 3, wherein the air-conditioning refrigerating cycle has a bypass circuit through which refrigerant bypasses the fourth heat exchanger.

**5.** The refrigerating system according to claim 2, wherein the refrigerating machine comprises a third compressor, a condenser for heat-exchanging with the cold/hot water in the first cold/hot water thermal storage device, a third pressure-reducing device and an evaporator that are connected through a refrigerant pipe in this order.

**6.** The refrigerating system according to claim 2, wherein the refrigerating cycle for heat source is equipped with an air heat source type sixth heat exchanger between the first heat exchanger and the first pressure-reducing device.

**7.** The refrigerating system according to claim 2, further

comprising a controller for operating the refrigerating cycle for heat source with nighttime power.

**8.** The refrigerating system according to claim 2, wherein refrigerant with which a high-pressure side is set to supercritical pressure is filled in the refrigerating cycle for heat source.

FIG. 1

FIRST THERMAL STORAGE OPERATION

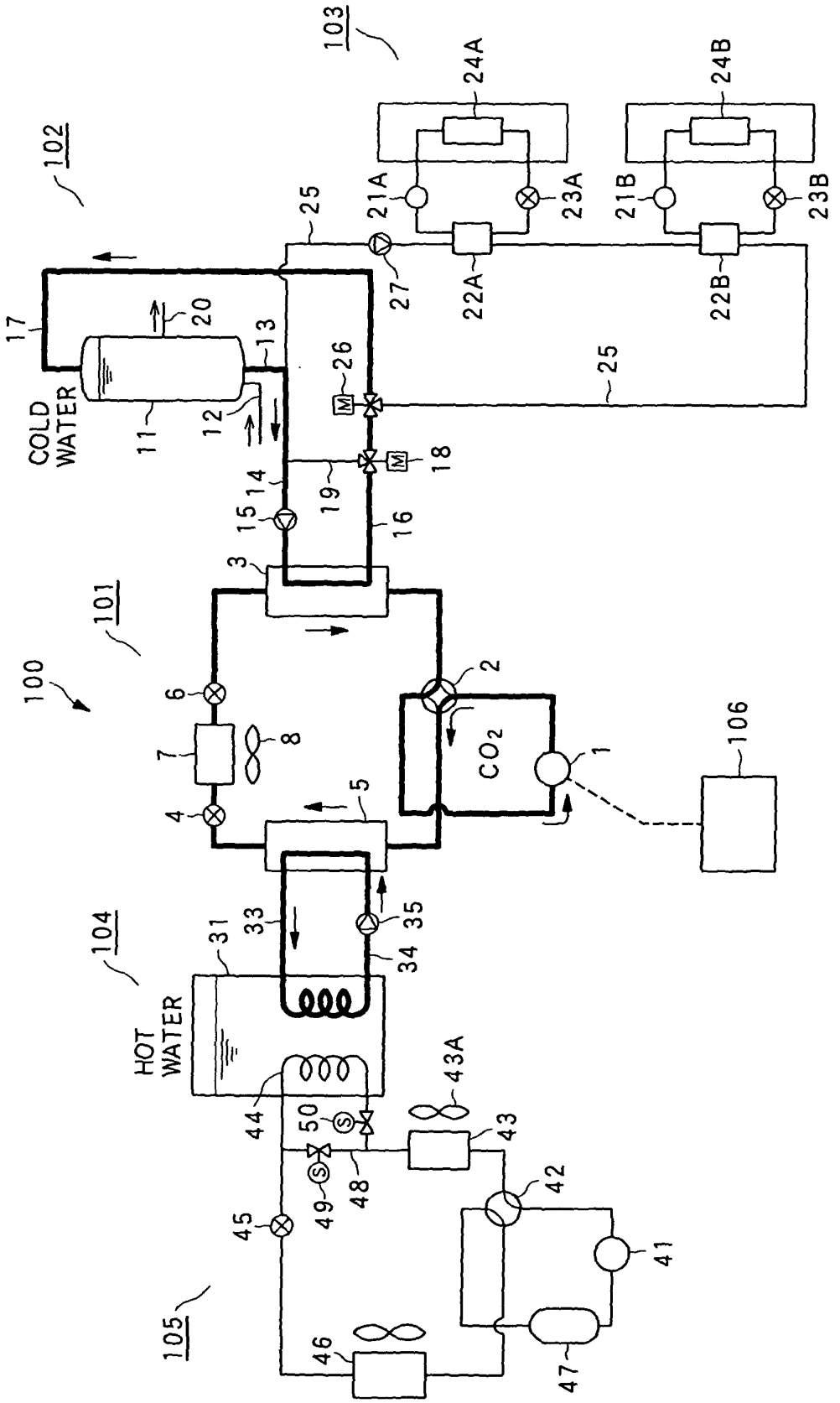

FIG. 2

HEATING OPERATION

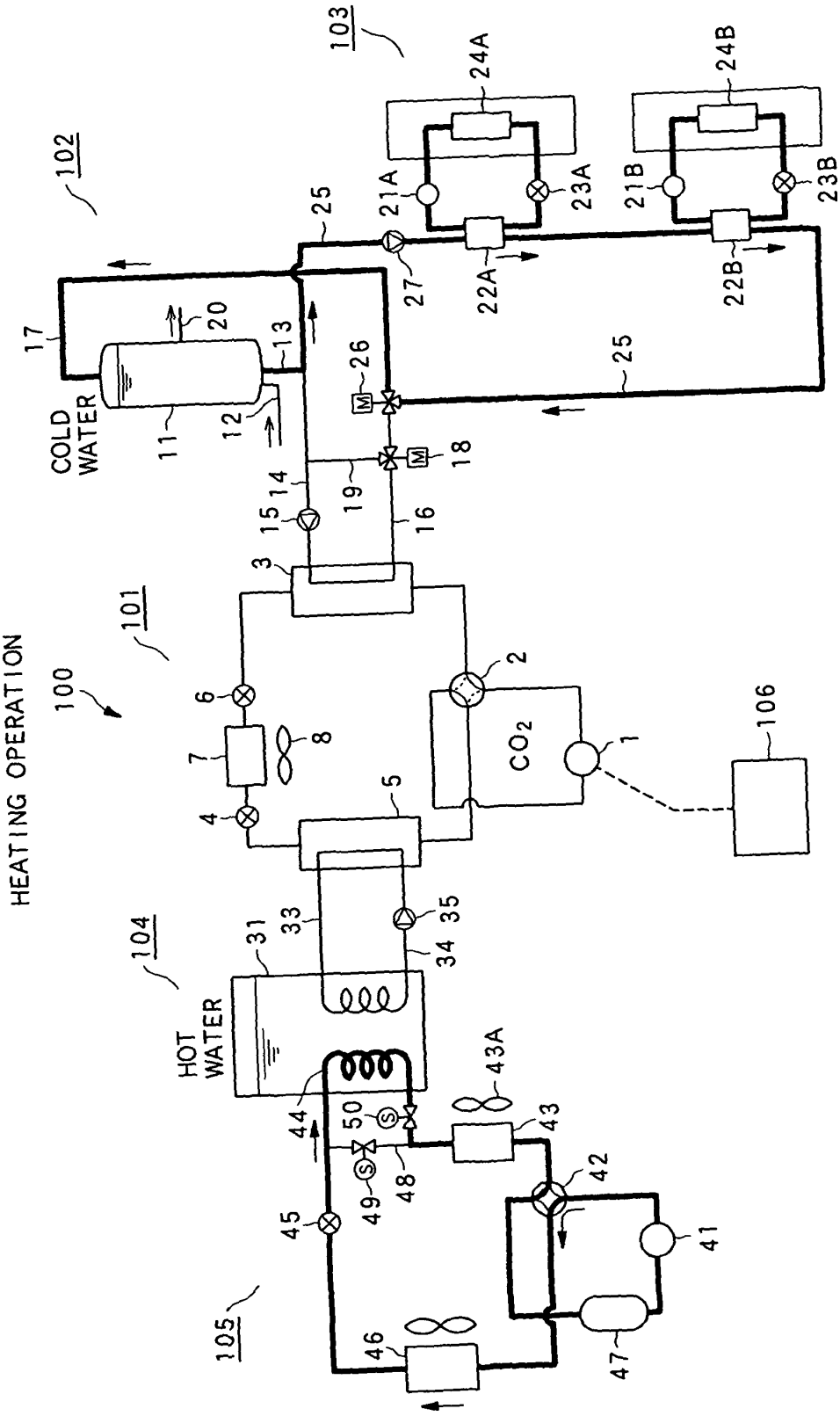

FIG. 3

SECOND THERMAL STORAGE OPERATION

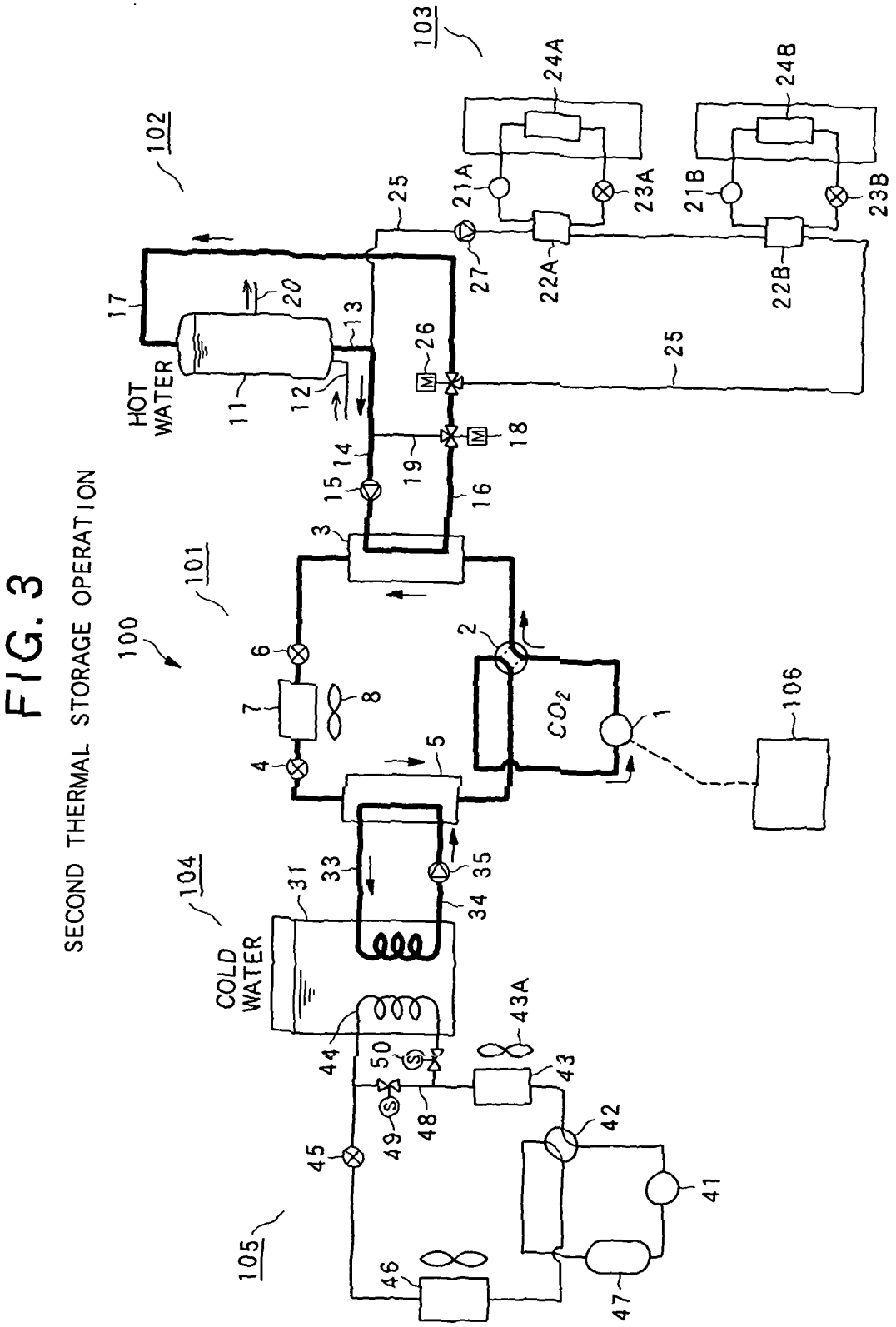

FIG. 4

COOLING OPERATION

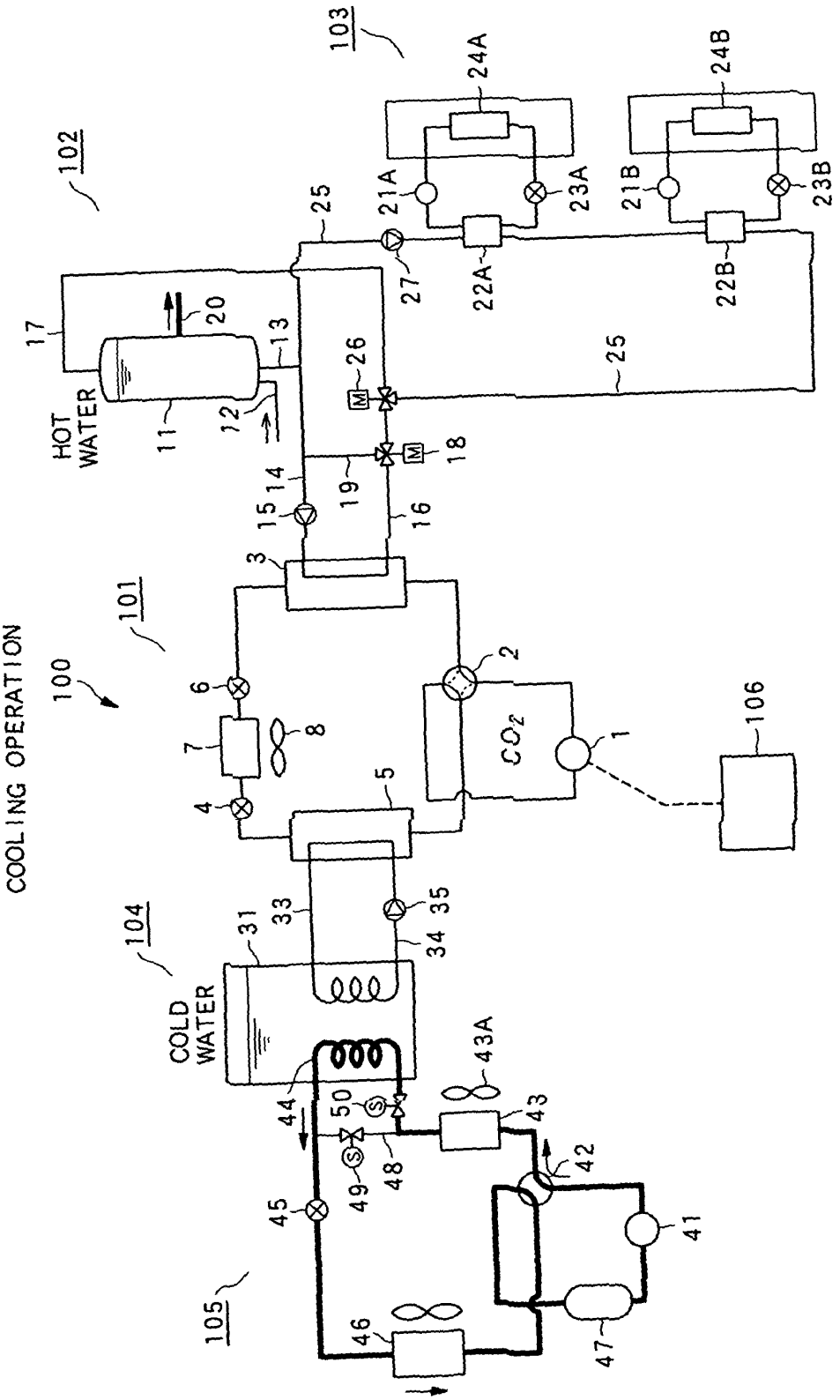

FIG. 5