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(54) **HOT WATER SUPPLY SYSTEM**

(57) A cascade refrigeration cycle is constituted of a low-temperature refrigeration cycle (Rb) that needs a four-way valve (11) and a high-temperature refrigeration cycle (Ra) that does not need the four-way valve (11) and an intermediate heat exchanger (5) included in each refrigeration cycle is caused to exchange heat. A hot water pipe (H) communicates with a water heat exchanger (2) in the high-temperature refrigeration cycle (Ra) and water or hot water is exchanged for high-temperature hot water, which is supplied to the side of use. A bypass circuit (B) has one end connected to a refrigerant pipe (P) between a high-temperature compressor (1) and the water heat exchanger in the high-temperature refrigeration cycle, has the other end connected to the refrigerant pipe between a high-temperature expansion device (4) and the intermediate heat exchanger, and has a fluid-controlled valve (8) provided in an intermediate portion. A controller (S) exercises specific control during defrosting operation for an evaporator in the low-temperature refrigeration cycle (Rb) by controlling the fluid-controlled valve (8) to open and the high-temperature expansion device to close during defrosting operation of an athermal exchanger (12) in the low-temperature refrigeration cycle (Rb) to enable reductions of parts costs and an efficient defrosting operation.

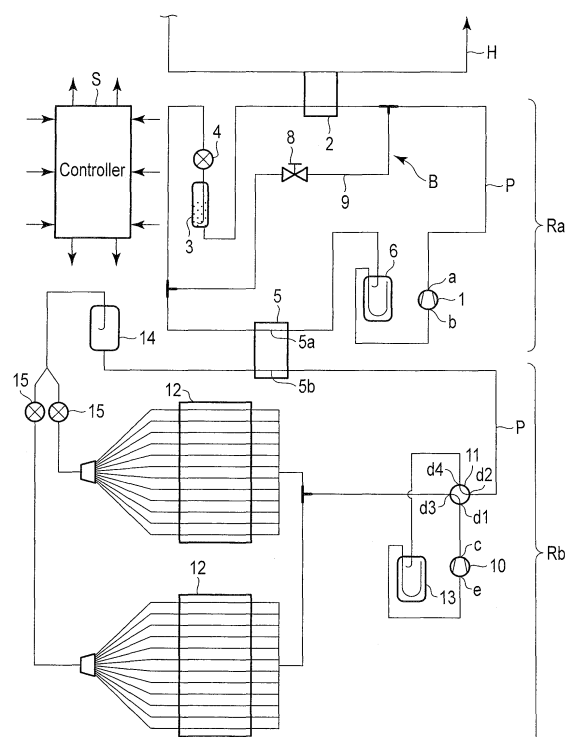


FIG. 1

Description

Technical Field

[0001] Embodiments described herein relate generally to a hot water supply system that supplies hot water by using a cascade refrigeration cycle.

Background Art

[0002] A cascade refrigeration cycle to obtain a high compression ratio by connecting a high-temperature refrigeration cycle and a low-temperature refrigeration cycle via an intermediate heat exchanger and causing the intermediate heat exchanger to exchange heat of a refrigerant circulating through the high-temperature refrigeration cycle and a refrigerant circulating through the low-temperature refrigeration cycle tends to be used more frequently (for example, Jpn. Pat. Appln. KOKAI Publication No. 2000-320914).

[0003] Then, a water heat exchanger is included as a condenser constituting the high-temperature refrigeration cycle and water or hot water is guided thereto via a hot water pipe. The water or hot water is exchanged for high-temperature hot water, which is supplied to the side of use to which the hot water pipe is connected. Therefore, an efficient hot water supply operation can be performed even in a cold district.

[0004] Incidentally, because an aero-thermal exchanger constituting the low-temperature refrigeration cycle during hot water supply operation is caused to act as an evaporator in the hot water supply system, frost formation on the aero-thermal exchanger accompanying an operation particularly under low outdoor temperature conditions is unavoidable. The heat exchange efficiency of the aero-thermal exchanger decreases if this state continues and thus, it becomes necessary to perform a defrosting operation.

Disclosure of Invention

[0005] To perform a defrosting operation, a four-way valve of the high-temperature refrigeration cycle and a four-way valve of the low-temperature refrigeration cycle are switched in the reverse direction to reverse the circulation direction of the refrigerant. Hot water guided into the water heat exchanger of the high-temperature refrigeration cycle is used as a heat source for defrosting and thus, a high pressure and a discharge temperature during defrosting operation can be maintained. Because a high-temperature gas refrigerant is directly guided into the aero-thermal exchanger of the low-temperature refrigeration cycle, the aero-thermal exchanger can be defrosted efficiently.

[0006] On the other hand, heat is absorbed from hot water guided into the water heat exchanger, disadvantageously lowering the temperature of the hot water.

[0007] Moreover, the four-way valve is expensive and

if possible, the cost should be reduced through the reduction of parts costs by removing the four-way valve and pipes connected to the four-way valve. In addition, there is an increasing demand for obtaining improvement of workability of plumbing by making an installation space for the four-way valve and connection pipes unnecessary.

[0008] However, if the four-way valves for both the low-temperature refrigeration cycle and the high-temperature refrigeration cycle are removed, it becomes impossible to maintain a high pressure and a discharge temperature during defrosting operation due to the lack of a heat source for defrosting so that an efficient defrosting operation may not be performed or defrosting may not be completed without a sufficient heat source. Therefore, it is necessary to consider removing the four-way valve while ensuring a heat source for defrosting operation.

[0009] The present embodiment has been made based on the above circumstances and a hot water supply system capable of reducing parts costs and performing an efficient defrosting operation by including the cascade refrigeration cycle and exercising special control for defrosting operation of an evaporator of the low-temperature refrigeration cycle is provided.

[0010] In order to satisfy the object, a hot water supply system of the present invention comprises, a cascade refrigeration cycle constituted of a low-temperature refrigeration cycle communicatively connecting a low-temperature compressor, a four-way valve, an intermediate heat exchanger, a low-temperature expansion device, and an evaporator via a refrigerant pipe and a high-temperature refrigeration cycle communicatively connecting a high-temperature compressor, a water heat exchanger, a high-temperature expansion device, and the intermediate heat exchanger via the refrigerant pipe to cause the intermediate heat exchanger to exchange heat of a refrigerant guided to the low-temperature refrigeration cycle and a refrigerant guided to the high-temperature refrigeration cycle, a hot water pipe communicating with the water heat exchanger in the high-temperature refrigeration cycle to cause circulating water or hot water and the refrigerant guided to the high-temperature refrigeration cycle to exchange heat and to supply the heat to a side of use, a bypass circuit whose one end is connected to the refrigerant pipe between the high-temperature compressor and the water heat exchanger in the high-temperature refrigeration cycle, whose other end is connected to the refrigerant pipe between the high-temperature expansion device and the intermediate heat exchanger in the high-temperature refrigeration cycle, and having a fluid-controlled valve in an intermediate portion thereof and a control unit that exercises control so that the fluid-controlled valve of the bypass circuit is opened and the high-temperature expansion device in the high-temperature refrigeration cycle is closed during a defrosting operation for the evaporator in the low-temperature refrigeration cycle.

Brief Description of Drawings

[0011]

FIG. 1 is a block diagram of a refrigeration cycle of a hot water supply system according to the present embodiment.

Best Mode for Carrying Out the Invention

[0012] FIG. 1 is a block diagram of a refrigeration cycle of a hot water supply system and shows particularly a refrigeration cycle switchover state during defrosting operation.

[0013] The hot water supply system is constituted of a high-temperature refrigeration cycle Ra, a hot water pipe H, a low-temperature refrigeration cycle Rb, and a controller (control unit) S.

[0014] The high-temperature refrigeration cycle Ra will first be described. A discharge portion a of a high-temperature compressor 1, a water heat exchanger 2, a liquid receiver 3, a high-temperature expansion device 4, a heat sink 5a of an intermediate heat exchanger 5, and a gas liquid separation device 6 are connected in succession via a refrigerant pipe P and the gas liquid separation device 6 is communicatively connected to a suction portion b of the high-temperature compressor 1.

[0015] Regardless of the hot water supply operation and the defrosting operation described later, a refrigerant compressed and discharged by the high-temperature compressor 1 is guided in the sequence of water heat exchanger 2 → liquid receiver 3 → high-temperature expansion device 4 → heat sink 5a of intermediate heat exchanger 5 → gas liquid separation device 6 → high-temperature compressor 1. Thus, the water heat exchanger 2 acts as a condenser and the heat sink 5a of the intermediate heat exchanger 5 acts as an evaporator.

[0016] A bypass circuit B is provided in the high-temperature refrigeration cycle Ra. The bypass circuit B is formed of a bypass pipe 9 whose one end is connected to the refrigerant pipe P between the discharge portion a of the high-temperature compressor 1 and the water heat exchanger 2, whose other end is connected to a refrigerant pipe P between the high-temperature expansion device 4 and the heat sink 5a of the intermediate heat exchanger 5, and having a fluid-controlled valve 8 in an intermediate portion.

[0017] The hot water pipe H has one end portion connected to a hot water return pipe or a return buffer tank and the other end portion connected to a hot water outlet pipe or a supply buffer tank (none of the above is illustrated).

[0018] The intermediate portion of the hot water pipe H communicates with the water heat exchanger 2 constituting the high-temperature refrigeration cycle Ra so that water or hot water guided into the hot water pipe H and a refrigerant guided into the water heat exchanger 2 can exchange heat.

[0019] In the low-temperature refrigeration cycle Rb, a discharge portion c of a low-temperature compressor 10 and a first port d1 of a four-way valve 11 are connected via the refrigerant pipe P and a radiating portion 5b of the intermediate heat exchanger 5 is connected to a second port d2 of the four-way valve 11 via the refrigerant pipe P. A third port d3 of the four-way valve 11 is connected to two aero-thermal exchanger 12, 12 via the refrigerant pipe P divided into two pipes in an intermediate portion thereof.

[0020] A fourth port d4 of the four-way valve 11 is connected to a suction portion e of the low-temperature compressor 10 via the refrigerant pipe P through a gas liquid separation device 13. On the other hand, the radiating portion 5b of the intermediate heat exchanger 5 is connected to a liquid receiver 14 via the refrigerant pipe P and the liquid receiver 14 and the two aero-thermal exchangers 12 are connected via the refrigerant pipe P divided into two pipes in an intermediate portion, each of which having a low-temperature expansion device 15.

[0021] In the low-temperature refrigeration cycle, a refrigerant compressed and discharged by the low-temperature compressor 10 is guided in the sequence of four-way valve 11 → radiating portion 5b of intermediate heat exchanger 5 → liquid receiver 14 → two low-temperature expansion devices 15 → two aero-thermal exchangers 12 → four-way valve 11 → liquid separation device 13 → low-temperature compressor 10.

[0022] Thus, the radiating portion 5b of the intermediate heat exchanger 5 acts as a condenser and the aero-thermal exchanger 12 acts as an evaporator.

[0023] In the defrosting operation of the aero-thermal exchanger 12 described later, the four-way valve 11 is switched to the direction shown in FIG. 11 and a refrigerant compressed and discharged by the low-temperature compressor 10 is guided in the sequence of four-way valve 11 → two aero-thermal exchangers 12 → two low-temperature expansion devices 15 → liquid receiver 14 → radiating portion 5b of intermediate heat exchanger 5 → four-way valve 11 → liquid separation device 13 → low-temperature compressor 10.

[0024] In this case, the aero-thermal exchanger 12 acts as a condenser and the radiating portion of the intermediate heat exchanger 5 acts as an evaporator.

[0025] The controller S receives a detection signal from temperature sensors provided in the discharge portions a, c and the suction portions b, e of the high-temperature compressor 1 and the low-temperature compressor 10 respectively, pressure sensors provided in the discharge portions a, c and the suction portions b, e, a temperature sensor provided in the water heat exchanger 2, temperature sensors provided in the heat sink 5a and the radiating portion 5b of the intermediate heat exchanger 5, a temperature sensor (none of the sensors is illustrated) provided in the aero-thermal exchanger 12 and the like.

[0026] Further, the controller S performs an operation after receiving an instruction signal from a remote controller (remocon) and compares the operation result with

a stored reference value (thermal capability, the temperature of the intermediate heat exchanger 5 and the like) to control the operating frequency of the high-temperature compressor 1 and the low-temperature compressor 10.

[0027] Further, the controller S calculates a superheat amount (hereinafter, referred to as an "SH amount") of a heat exchanger from a difference between a refrigerant temperature of the heat exchanger and a refrigerant temperature on the suction side of a compressor to control the throttling amount of the high-temperature expansion device 4 and the low-temperature expansion device 15. Then, the controller S executes control to open or close the fluid-controlled valve 8 of the bypass circuit B.

[0028] The hot water supply system is configured as described above and the controller S during hot water supply operation controls the high-temperature refrigeration cycle Ra and the low-temperature refrigeration cycle Rb so that the refrigerant is guided and circulated as described above.

[0029] In the intermediate heat exchanger 5, the refrigerant is compressed by the radiating portion 5b on the side of the low-temperature refrigeration cycle Rb to give off heat of condensation and the refrigerant is evaporated by the heat sink 5a on the side of the high-temperature refrigeration cycle Ra while the heat of condensation being absorbed.

[0030] Therefore, the difference of temperature between the evaporating temperature in the aero-thermal exchanger 12 and the condensing temperature in the water heat exchanger 2 increases in the hot water supply system as a whole so that a high compression ratio can be obtained. In the water heat exchanger 2 executing a condensation function in the high-temperature refrigeration cycle Ra, water or hot water guided into the hot water pipe H absorbs high heat of condensation and the temperature thereof rises efficiently.

[0031] The water or hot water is exchanged for high-temperature hot water in the water heat exchanger 2 and circulated by way of water heat exchanger 2 → supply buffer tank of hot water → return buffer-tank on load side → water heat exchanger 2.

[0032] Particularly, if the hot water supply operation is continued under low outdoor temperature conditions, the aero-thermal exchanger 12 in the low-temperature refrigeration cycle Rb executes an evaporation function and thus, condensed water generated here is frozen to form frost, which adheres to the aero-thermal exchanger 12. The thickness of frost increases with the passage of time, decreasing the heat exchange efficiency by the aero-thermal exchanger 12.

[0033] The controller S receives not only a detection signal from the temperature sensor attached to the aero-thermal exchanger 12, but also a detection signal from other sensors to determine whether a defrosting operation of the aero-thermal exchanger 12 is needed. The defrosting operation is performed based on the result of the determination and actually, the controller S exercises

the control described below immediately before starting a defrosting operation.

[0034] That is, the controller S exercises throttling control of the high-temperature expansion device 4 provided in the high-temperature refrigeration cycle Ra in the timing immediately before starting a defrosting operation. Thus, the flow rate of the refrigerant guided from the high-temperature expansion device 4 into the heat sink 5a of the intermediate heat exchanger 5 decreases in the high-temperature refrigeration cycle Ra.

[0035] Therefore, the amount of absorbed heat by the heat sink 5a of the intermediate heat exchanger 5 decreases and the temperatures of the heat sink 5a and the radiating portion 5b rise and also the temperature of the intermediate heat exchanger 5 as a whole rises. At this point, there is no need to change the operating frequency of the high-temperature compressor 1 in the high-temperature refrigeration cycle Ra and the low-temperature compressor 10 in the low-temperature refrigeration cycle Rb.

[0036] The suction temperature and suction pressure of the high-temperature compressor 1 communicatively connected via the heat sink 5a of the intermediate heat exchanger 5 and the refrigerant pipe P also rise, but the circulating amount of refrigerant in the high-temperature refrigeration cycle Ra decreases and thus, the discharge pressure hardly rises, leading to a lower compression ratio of the high-temperature compressor 1.

[0037] However, the suction temperature of the high-temperature compressor 1 rises and a difference from the evaporating temperature of the heat sink 5a of the intermediate heat exchanger executing an evaporation function increases and thus, the so-called SH amount becomes excessive and the discharge temperature of the high-temperature compressor 1 rises. In the low-temperature refrigeration cycle Rb, with the rise in temperature of the radiating portion 5b of the intermediate heat exchanger, the compression ratio increases and the discharge temperature of the low-temperature compressor 10 rises.

[0038] The controller S exercises, as described above, throttling control of the high-temperature expansion device 4 of the high-temperature refrigeration cycle Ra in the timing immediately before starting a defrosting operation of the aero-thermal exchanger 12. Therefore, the rise in evaporating temperature of the heat sink 5a of the intermediate heat exchanger 5, the rise in condensing temperature of the radiating portion 5b, and the rise in discharge temperature of the high-temperature compressor 1 and the low-temperature compressor 10 are obtained in a short time without changing the operating frequency of the high-temperature compressor 1 and the low-temperature compressor 10.

[0039] In the high-temperature refrigeration cycle Ra, the temperature of low-pressure piping parts ranging from the high-temperature expansion device 4 to the high-temperature compressor 1 via the intermediate heat exchanger 5 rises and also the temperature of the com-

pressor body of the high-temperature compressor 1 and high-pressure piping parts ranging from the high-temperature compressor 1 to the water heat exchanger 2 rises so that heat can be stored.

[0040] At the same time, in the low-temperature refrigeration cycle Rb, the temperature of high-pressure piping parts ranging from the high-temperature compressor 1 and the low-temperature compressor 10 to the low-temperature expansion device 15 via the four-way valve 11 and the intermediate heat exchanger 5 rises so that heat can be stored.

[0041] After maintaining the above heat storage operation for a predetermined time, the controller S controls the start of an actual defrosting operation of the aero-thermal exchanger 12. In this case, the fluid-controlled valve 8 of the bypass circuit B is opened and the also the four-way valve 11 of the low-temperature refrigeration cycle Rb is switched to cause the refrigerant to circulate in the direction opposite to the refrigerant circulation direction heretofore.

[0042] However, if the four-way valve 11 is instantaneously switched while continuing to drive the low-temperature compressor 10 in the low-temperature refrigeration cycle Rb, a collision of refrigerant inside the four-way valve 11 occurs and noise is caused. If such switching noise of the four-way valve 11 is increased and leaked to the outside, quiet operation is impaired.

[0043] Thus, the controller S stops the operation of the low-temperature compressor 10 once (a few tens of seconds to a few minutes) and also exercises necessary control such as opening an equalizing pipe to balance the pressure on the high-pressure side and the low-pressure side in the low-temperature refrigeration cycle Rb. Then, the flow of the refrigerant inside the switching valve is decreased by switching the four-way valve 11 so that switching noise can be inhibited by quieting the collision.

[0044] Further, as the necessary control, the controller S totally closes the high-temperature expansion device 4 while continuing the operation of the high-temperature compressor 1 in the high-temperature refrigeration cycle Ra. Thus, the high pressure of the high-temperature refrigeration cycle Ra is maintained and the refrigerant recovered from the heat sink 5a of the intermediate heat exchanger 5 and discharged from the high-temperature compressor 1 stores heat by remaining in the water heat exchanger 2 as a condenser and the liquid receiver 3 as a high-temperature liquid refrigerant.

[0045] The amount of absorbed heat from the heat sink 5a can be restrained by the refrigerant not being supplied to the intermediate heat exchanger 5 so that a heat storage effect can be maintained.

[0046] A pump-down (refrigerant recovery) operation is performed in the high-temperature refrigeration cycle Ra and thus, it is desirable to extend the operation duration by reducing the operating frequency of the high-temperature compressor 1 when necessary so that an operation stop should not occur due to a pressure drop of low pressure.

[0047] After exercising the above control for the predetermined time, the controller S controls the fluid-controlled valve 8 of the bypass circuit B to open while continuing the operation of the high-temperature compressor 1 in the high-temperature refrigeration cycle Ra. Further, the controller S switches the four-way valve 11 in the low-temperature refrigeration cycle Rb and also restarts the operation of the low-temperature compressor 10.

[0048] At this point, the pressure on the high-pressure side and the low-pressure side is balanced in the low-temperature refrigeration cycle Rb and thus, switching noise of the four-way valve 11 is hardly generated.

[0049] A hot gas as a refrigerant gas at high temperature and pressure discharged from the high-temperature compressor 1 is guided to the bypass circuit B and then guided into the heat sink 5a of the intermediate heat exchanger 5 via the fluid-controlled valve 8 to give off high heat. Also in the process in which high pressure of the high-temperature refrigeration cycle Ra drops, a liquid refrigerant present in the water heat exchanger 2 as a condenser and the liquid receiver 3 is depressed and boiled before being gasified to circulate in the opposite direction in the refrigeration cycle.

[0050] Then, the gasified refrigerant is guided to the bypass circuit B and then guided into the intermediate heat exchanger 5 via the fluid-controlled valve 8. Accordingly, heat is also absorbed from hot water on the side of use to provide a portion of the heat source needed for defrosting operation.

[0051] In the low-temperature refrigeration cycle Rb, the refrigerant circulates in the direction opposite to the direction during hot water supply operation using the intermediate heat exchanger 5 as a heat source and the refrigerant is condensed in each of the aero-thermal exchangers 12 to give off heat of condensation. Thus, frost adhering to the aero-thermal exchanger 12 is gradually melted and drops as drain water. The frost is quickly thinned to expose the surface of the aero-thermal exchanger 12.

[0052] As a result of the control exercised in the timing immediately before starting a defrosting operation described above, heat stored in low-pressure piping parts ranging from the high-temperature expansion device 4 to the high-temperature compressor 1 via the intermediate heat exchanger 5 in the high-temperature refrigeration cycle Ra, high-pressure piping parts ranging from the high-temperature compressor 1 and the high-temperature compressor 1 to the water heat exchanger 2 in the high-temperature refrigeration cycle Ra, and high-pressure piping parts ranging from the low-temperature compressor 10 and the low-temperature compressor 10 to the low-temperature expansion device 15 via the intermediate heat exchanger 5 in the low-temperature refrigeration cycle Rb is given off at this point.

[0053] All stored heat is used to defrost the aero-thermal exchanger 12, further promoting a defrosting operation.

[0054] If the heat storage source is used up after a long

time needed for defrosting operation of the aero-thermal exchanger 12, high pressure of the high-temperature refrigeration cycle Ra and the low-temperature refrigeration cycle Rb drops and input of the high-temperature compressor 1 and the low-temperature compressor 10 becomes minimum, which may lead to a state in which compressor input cannot be used as a heat source.

[0055] Then, when the controller S detects that high pressure of the high-temperature refrigeration cycle Ra has dropped to a predetermined pressure or less, the controller S executes control to totally close the fluid-controlled valve 8 of the bypass circuit B and also executes control to open the high-temperature expansion device 4 totally or to an appropriate degree of opening.

[0056] Accordingly, a discharge gas at low temperature in the high-temperature refrigeration cycle Ra can be warmed by heat of hot water guided into the water heat exchanger 2 so that a heat source of the defrosting operation of the aero-thermal exchanger 12 can be ensured. The temperature drop of hot water guided into the water heat exchanger 2 can be limited to less than 1 degree.

[0057] If the high-temperature expansion device 4 is adjusted to an appropriate degree of opening, instead of totally opening the high-temperature expansion device 4, high pressure of the high-temperature refrigeration cycle Ra can be slightly increased and thus, the amount of heat by input of the high-temperature compressor 1 can be ensured and also the supply amount of hot gas to the intermediate heat exchanger 5 can be adjusted.

[0058] The defrosting operation of the aero-thermal exchanger 12 is performed as described above and thus, the need for the four-way valve in the high-temperature refrigeration cycle Ra can be eliminated and also the need for piping parts to be connected to the four-way valve can be eliminated. Therefore, parts costs can be reduced and improvement in workability and also cost reductions can be achieved due to eliminated piping, contributing to miniaturization of devices from reduced installation space thereof.

[0059] The bypass pipe 9 and the fluid-controlled valve 8 constituting the bypass circuit B are needed as a substitute for eliminating the need for the four-way valve in the high-temperature refrigeration cycle Ra, but both ends of the bypass pipe 9 only need to be connected to an intermediate portion of the refrigerant pipe P constituting the high-temperature refrigeration cycle Ra and the fluid-controlled valve 8 can be installed simply as an on-off valve so that the effect on cost can be reduced to a minimum.

[0060] The rise in low pressure of the high-temperature refrigeration cycle Ra, the rise in discharge temperature accompanying an increase in SH amount, and further the rise in high pressure and the rise in discharge temperature of the low-temperature refrigeration cycle Rb can be obtained by relatively simple control of only throttling the high-temperature expansion device 4 immediately before a defrosting operation being started.

[0061] As a result, the amount of heat needed for defrosting operation can internally be stored in low-pressure piping parts, the high-temperature compressor 1, and high-pressure piping parts in the high-temperature refrigeration cycle Ra and the low-temperature compressor 10 and high-pressure piping parts in the low-temperature refrigeration cycle Rb so that defrosting efficiency can be improved.

[0062] Before actually starting a defrosting operation after completion of internal heat storage, the operation of the low-temperature compressor 10 in the low-temperature refrigeration cycle Rb is stopped for a predetermined time to balance the pressure on the high-pressure side and the low-pressure side and then the four-way valve 11 is switched and thus, switching noise can be reduced and quiet operation can be achieved.

[0063] Then, the fluid-controlled valve 8 of the bypass circuit B is controlled to open and the high-temperature expansion device 4 is controlled to close while the operation of the high-temperature compressor 1 being continued. Therefore, hot water as a heat source for defrosting is hardly used so that the temperature drop of hot water guided into the hot water pipe H can be limited. Thus, the heat storage state can be retained while high pressure of the high-temperature refrigeration cycle Ra being maintained, which is helpful in reducing the defrosting time.

[0064] If the high pressure of the high-temperature refrigeration cycle Ra falls below a threshold while continuing a defrosting operation, the fluid-controlled valve 8 of the bypass circuit B is controlled to close and the high-temperature expansion device 4 is controlled to open totally or to an appropriate degree of opening. Therefore, even if input of the high-temperature compressor 1 and the low-temperature compressor 10 is in a minimum state after internal heat storage being used up, a discharge gas of the high-temperature compressor 1 can be warmed by hot water of the hot water pipe H so that the heat source can be ensured, reducing the risk of incomplete defrosting.

[0065] In the foregoing, the present embodiment has been described, but the above embodiment is presented as an example and is not intended to limit the scope of embodiments. Such new embodiments can be carried out in various other forms and various omissions, substitutions, and alterations can be made without deviating from the spirit thereof. Such embodiments and modifications are included in the scope and spirit of the invention and also included in the scope of the invention described in claims and equivalents thereof.

Claims

1. A hot water supply system, **characterized by** comprising:

a cascade refrigeration cycle constituted of a

low-temperature refrigeration cycle communicatively connecting a low-temperature compressor, a four-way valve, an intermediate heat exchanger, a low-temperature expansion device, and an evaporator via a refrigerant pipe and a high-temperature refrigeration cycle communicatively connecting a high-temperature compressor, a water heat exchanger, a high-temperature expansion device, and the intermediate heat exchanger via the refrigerant pipe to cause the intermediate heat exchanger to exchange heat of a refrigerant guided to the low-temperature refrigeration cycle and a refrigerant guided to the high-temperature refrigeration cycle;

a hot water pipe communicating with the water heat exchanger in the high-temperature refrigeration cycle to cause circulating water or hot water and the refrigerant to exchange heat and to supply the heat to a side of use;

a bypass circuit whose one end is connected to the refrigerant pipe between the high-temperature compressor and the water heat exchanger in the high-temperature refrigeration cycle, whose other end is connected to the refrigerant pipe between the high-temperature expansion device and the intermediate heat exchanger in the high-temperature refrigeration cycle, and having a fluid-controlled valve in an intermediate portion thereof; and

a control unit that exercises control so that the fluid-controlled valve of the bypass circuit is opened and the high-temperature expansion device in the high-temperature refrigeration cycle is closed during a defrosting operation for the evaporator in the low-temperature refrigeration cycle.

2. The hot water supply system according to claim 1, **characterized in that** the control unit controls the refrigerant to circulate in a sequence of the low-temperature compressor to the four-way valve to the intermediate heat exchanger to the low-temperature expansion device to the evaporator to the low-temperature compressor in the low-temperature refrigeration cycle and controls the refrigerant to circulate in the sequence of the high-temperature compressor to the water heat exchanger to the high-temperature expansion device so the intermediate heat exchanger in the high-temperature refrigeration cycle during a hot water supply operation, exercises control to perform an operation by throttling the high-temperature expansion device in the high-temperature refrigeration cycle to reduce a circulation amount of the refrigerant before starting the defrosting operation for the evaporator, and

switches the four-way valve in the low-temperature refrigeration cycle during the defrosting operation for the evaporator to control the refrigerant to circulate in the sequence of the low-temperature compressor to the four-way valve to the evaporator to the low-temperature expansion device to the intermediate heat exchanger to the low-temperature compressor.

3. The hot water supply system according to claim 2, **characterized in that** the control unit controls the high-temperature expansion device to totally close while continuing the operation of the high-temperature compressor in the high-temperature refrigeration cycle and also exercises control to stop the operation of the low-temperature compressor in the low-temperature refrigeration cycle once when the four-way valve in the low-temperature refrigeration cycle is switched before starting the defrosting operation for the evaporator
4. The hot water supply system according to claim 2, **characterized in that** the control unit exercises control so that the fluid-controlled valve of the bypass circuit is closed and the high-temperature expansion device in the high-temperature refrigeration cycle is opened when high pressure of the in the high-temperature refrigeration cycle drops to a predetermined pressure or less during the defrosting operation for the evaporator.

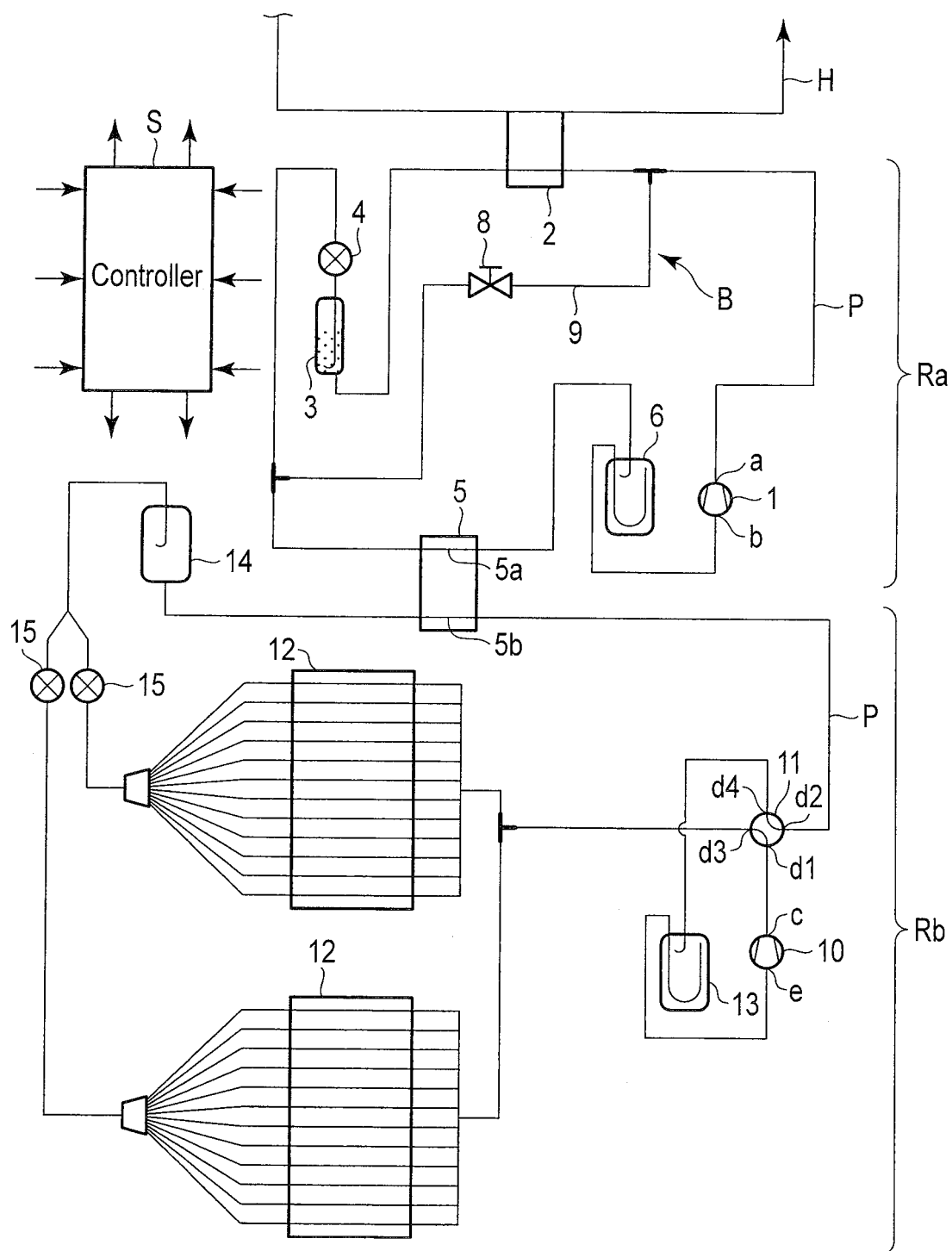


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/071326

A. CLASSIFICATION OF SUBJECT MATTER

F25B47/02(2006.01) i, F24H1/00(2006.01) i, F25B7/00(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)

F25B47/02, F24H1/00, F25B7/00

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	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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.
Y	JP 2010-196950 A (Daikin Industries, Ltd.), 09 September 2010 (09.09.2010), paragraphs [0285] to [0305]; fig. 16 & WO 2010/098061 A1	1-4
Y	JP 2003-74998 A (Sanyo Electric Co., Ltd.), 12 March 2003 (12.03.2003), paragraphs [0002] to [0003] & KR 10-2003-0020837 A & CN 1403762 A	1-4
Y	JP 2002-243276 A (Toshiba Carrier Corp.), 28 August 2002 (28.08.2002), paragraph [0094] (Family: none)	1-4

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search
13 December, 2011 (13.12.11)Date of mailing of the international search report
27 December, 2011 (27.12.11)Name and mailing address of the ISA/
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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/071326

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 4-24478 A (Daikin Industries, Ltd.), 28 January 1992 (28.01.1992), page 5, upper left column, line 15 to lower right column, line 5 (Family: none)	1-4
Y	JP 61-175430 A (Tohoku Electric Power Co., Inc.), 07 August 1986 (07.08.1986), page 3, lower left column, lines 9 to 12; page 4, upper left column, line 16 to upper right column, line 4 (Family: none)	2-4
Y	JP 10-96573 A (Daikin Industries, Ltd.), 14 April 1998 (14.04.1998), paragraph [0002] (Family: none)	3, 4
Y	JP 11-30461 A (Matsushita Electric Industrial Co., Ltd.), 02 February 1999 (02.02.1999), paragraph [0006] (Family: none)	3, 4
Y	JP 4-288463 A (Mitsubishi Electric Corp.), 13 October 1992 (13.10.1992), paragraphs [0010] to [0011] (Family: none)	4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2000320914 A [0002]