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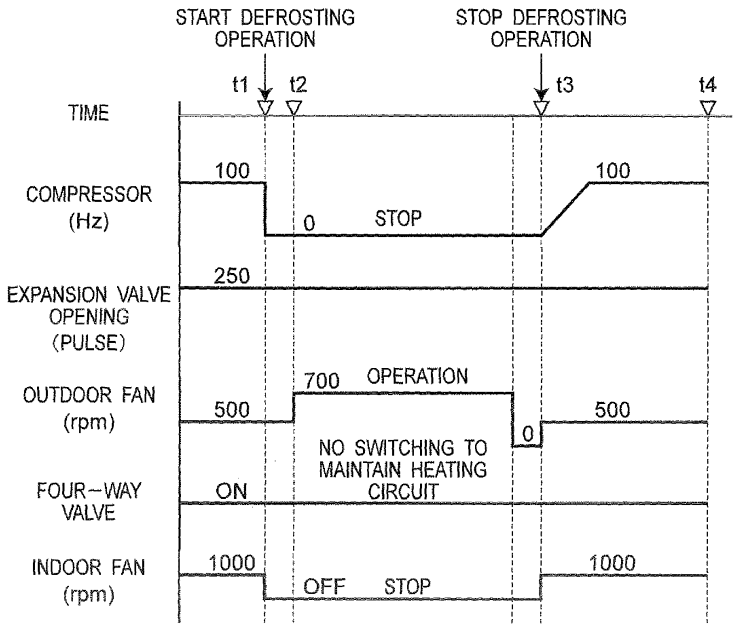
(54) **AIR CONDITIONER**

(57) An air conditioner includes a compressor 1, a four-way valve 2, an indoor heat exchanger 3, a pressure reducing device 4, and an outdoor heat exchanger 5, all connected in series via a refrigerant circuit to define a heat pump refrigerating cycle. The air conditioner also includes an indoor fan 3 for exchanging heat between the indoor heat exchanger 3 and indoor air, an outdoor fan 8 for exchanging heat between the outdoor heat exchanger 5 and outdoor air, and an outdoor temperature sensor 6 for detecting an outdoor temperature. When the outdoor temperature detected by the outdoor temperature sensor 6 is greater than or equal to a predetermined temperature, the compressor is stopped, and the outdoor fan is operated to defrost the outdoor heat exchanger 5.

Fig.4



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Description

Technical Field

[0001] The present invention relates to an air conditioner and, in particular, to an air conditioner capable of removing frost that has adhered to an outdoor heat exchanger with use of a heat pump.

Background Art

[0002] In a defrosting system for a conventional heat pump air conditioner, a four-way valve is generally switched over to cause a refrigerant to flow in an opposite direction in a refrigerating cycle. Fig. 10 is a timing chart indicating a control for the conventional air conditioner in which defrosting is conducted by switching the four-way valve.

[0003] During heating, when a defrosting start signal is received at time t1, a compressor frequency is reduced, and an opening of an expansion valve is set to a predetermined one. The four-way valve is subsequently switched over from a heating circuit to a cooling circuit, and an outdoor fan and an indoor fan are both brought to a stop. That is, in a defrosting operation, a direction of flow of the refrigerant during the heating is the same as that during cooling, thereby causing a high-temperature and high-pressure refrigerant to flow through an outdoor heat exchanger to melt frost adhering to the outdoor heat exchanger.

[0004] In this defrosting system, an input to a compressor is utilized as heat of melting for the defrost adhering to the outdoor heat exchanger, and a general air conditioner for heating a 12-mat room consumes an input of about 600-1000W during the defrosting operation. Also, because an indoor heat exchanger is used as an evaporator during defrosting, a room temperature reduces to thereby cause an uncomfortable operation in which a user or users feel cold. Further, at low temperatures, the defrosting operation is conducted about once an hour during heating, and this is detrimental to energy saving and comfort.

[0005] To solve this kind of problem, an air conditioner capable of enhancing comfort and a running performance has been proposed (see, for example, Patent Document 1).

[0006] Fig. 11 depicts a refrigerating cycle of the conventional air conditioner as disclosed in Patent Document 1. The conventional air conditioner as shown in Fig. 11 includes a compressor 101, a four-way valve 102, an indoor heat exchanger 103, an expansion valve (or capillary tube) 104, and an outdoor heat exchanger 105, all connected in series via a refrigerant circuit to define a heat pump refrigerating cycle. The indoor heat exchanger 103 is provided with an indoor fan 106, and the outdoor heat exchanger 105 is provided with an outdoor fan 107 and a piping temperature sensor 108 for detecting a temperature of the outdoor heat exchanger 105. A control means 109 controls the defrosting operation based on the temperature detected by the piping temperature sensor 108.

[0007] More specifically, the control means 109 monitors detection results of the piping temperature sensor 108 for every predetermined period, and when the piping temperature sensor 108 consecutively detects temperatures less than a predetermined temperature more than the predetermined number of times, the defrosting operation for removing frost adhering to the outdoor heat exchanger 105 is conducted.

[0008] In this way, the defrosting operation for the outdoor heat exchanger 105 is conducted upon confirmation of the state of frost adhering to the outdoor heat exchanger 105 during the heat pump operation. By so doing, not only can the number of times of defrosting be minimized, but efficient heating operations can be also conducted without conducting unnecessary defrosting operations. At the same time, it becomes possible to restrain a reduction in room temperature, which has been hitherto caused by the defrosting operation, to enhance comfort.

Patent Document(s)

[0009] Patent Document 1: Japanese Laid-Open Patent Publication No. 60-133249

Summary of Invention

Problems to be Solved by Invention

[0010] However, the conventional defrosting control method as disclosed in Patent Document 1 has the following disadvantages.

[0011] Because the defrosting operation as set forth above is conducted by operating the compressor 101 under the condition in which the four-way valve 102 has been switched to the cooling circuit, the refrigerant actually flows through the indoor heat exchanger 103, though the number of times of a cold refrigerant flowing through the indoor heat exchanger 103 reduces. Accordingly, a chill a user or users feel and a reduction in room temperature, both caused by a stop of heating operations, are substantial, and this uncomfortable feeling is not removed. Also, efficient operations are possible without unnecessary defrosting operations of the outdoor exchanger 105, but an input to the compressor 101 is utilized as the quantity of heat during defrosting, thus resulting in low-efficiency defrosting.

[0012] The present invention has been developed to overcome the above-described disadvantages.

[0013] It is accordingly an objective of the present invention to provide an air conditioner capable of conducting a defrosting operation to melt frost with a considerably small input by making use of atmospheric heat. The air conditioner according to the present invention requires no complicated refrigerating cycle and employs component parts installed in a general refrigerating cycle and

in a general air conditioner. Also, the air conditioner according to the present invention does not allow a cold refrigerant to flow through an indoor heat exchanger during the defrosting operation to thereby reduce a room temperature drop and refrigerant sound during the defrosting operation.

Means to Solve Problems

[0014] In accomplishing the above objective, the air conditioner according to the present invention includes a compressor, a four-way valve, an indoor heat exchanger, a pressure reducing device, and an outdoor heat exchanger, all connected in series via a refrigerant circuit to define a heat pump refrigerating cycle. The air conditioner includes an indoor fan for exchanging heat between the indoor heat exchanger and indoor air, an outdoor fan for exchanging heat between the outdoor heat exchanger and outdoor air, and an outdoor temperature sensor for detecting an outdoor temperature. When the outdoor temperature detected by the outdoor temperature sensor is greater than or equal to a predetermined temperature, the compressor is stopped, and the outdoor fan is operated to defrost the outdoor heat exchanger.

[0015] The heat pump refrigerating cycle is held in a heating state during a defrosting operation for the outdoor heat exchanger.

[0016] It is preferred that a speed of the outdoor fan during the defrosting operation be set to a speed higher than that during a heating operation or a maximum speed.

[0017] An expansion valve is preferably used as the pressure reducing device, and the expansion valve is fully or almost fully closed immediately before or after the defrosting operation.

[0018] Before the defrosting operation is conducted, an operation frequency of the compressor may be reduced. In this case, the expansion valve is subsequently fully or almost fully closed, and after the compressor has been operated for a predetermined time period, the compressor is stopped, and the outdoor fan is operated.

[0019] Also, before the defrosting operation is conducted, the expansion valve may be fully or almost fully closed and subsequently opened for a predetermined time period, and the outdoor fan is operated thereafter.

[0020] Moreover, before the defrosting operation is conducted, the outdoor fan may be stopped, and the expansion valve may be fully or almost fully opened. In this case, upon operation of a predetermined time period, the compressor is stopped, and the outdoor fan is operated.

[0021] In another aspect of the present invention, an air conditioner includes a compressor, a four-way valve, an indoor heat exchanger, an expansion valve, and an outdoor heat exchanger, all connected in series via a refrigerant circuit to define a heat pump refrigerating cycle, and also includes an indoor fan for exchanging heat between the indoor heat exchanger and indoor air, an outdoor fan for exchanging heat between the outdoor heat exchanger and outdoor air, and an outdoor temperature sensor for detecting an outdoor temperature. When the outdoor temperature detected by the outdoor temperature sensor is less than a predetermined temperature, the heat pump refrigerating cycle is switched to a cooling circuit by the four-way valve, the compressor is subsequently stopped, the expansion valve is fully or almost fully closed, and the outdoor fan is operated to defrost the outdoor heat exchanger.

[0022] In this case, a time period during which the heat pump refrigerating cycle is being set to the cooling circuit upon switching of the four-way valve may be limited to a predetermined time period or less.

[0023] If an outdoor piping temperature sensor for detecting an outdoor piping temperature is provided, only when the outdoor piping temperature detected by the outdoor piping temperature sensor is less than a predetermined temperature, the heat pump refrigerating cycle can be switched to the cooling circuit by the four-way valve.

[0024] Also, when the outdoor temperature detected by the outdoor temperature sensor is greater than or equal to a predetermined temperature, a time period for operation of the outdoor fan is preferably set shorter than when the outdoor temperature is less than the predetermined temperature.

Effects of Invention

[0025] According to the present invention, when the outdoor temperature detected by the outdoor temperature sensor is greater than or equal to a predetermined value, the defrosting operation for defrosting the outdoor heat exchanger is conducted using atmospheric heat by stopping the compressor, thus resulting in energy saving and enhancing comfort.

[0026] Also, because defrosting by switching of the four-way valve and defrosting with use of atmospheric heat are both employed, the former is first conducted to melt part of frost adhering to a front surface of the outdoor heat exchanger, and the latter is subsequently conducted, thus resulting in energy saving and enhancing comfort.

Brief Description of Drawings

[0027]

Fig. 1 is a diagram of a refrigerating cycle of an air conditioner according to the present invention.

Fig. 2 is a control block diagram of the air conditioner of Fig. 1.

Fig. 3 is a flowchart indicating a control of the air conditioner of Fig. 1 during defrosting.

Fig. 4 is a timing chart indicating a control operation of the air conditioner according to the present invention when a defrosting operation with use of atmospheric heat is conducted.

Fig. 5 is a timing chart indicating another control operation of the air conditioner according to the present

invention when the defrosting operation with use of atmospheric heat is conducted.

Fig. 6 is a timing chart indicating a further control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

Fig. 7 is a timing chart indicating a still further control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

Fig. 8 is a timing chart indicating a yet further control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

Fig. 9 is a timing chart indicating a control operation of the air conditioner according to the present invention when a defrosting operation is conducted by switching a four-way valve.

Fig. 10 is a timing chart indicating a control for a conventional air conditioner in which defrosting is conducted by switching the four-way valve.

Fig. 11 is a diagram of a refrigerating cycle of another conventional air conditioner.

Description of Embodiments

[0028] Embodiments of the present invention are explained hereinafter with reference to the drawings, but the present invention is not limited by such embodiments.

(Basic Construction of Air Conditioner)

[0029] Fig. 1 is a diagram of a refrigerating cycle of an air conditioner according to the present invention, and Fig. 2 is a control block diagram of the air conditioner.

[0030] As shown in Fig. 1, the air conditioner according to the present invention includes an indoor unit 10 and an outdoor unit 11 connected to each other via a refrigerant circuit. The outdoor unit 11 includes a compressor 1, a four-way valve 2, a pressure reducing device 4, an outdoor heat exchanger 5, an outdoor temperature sensor 6 for detecting an outdoor temperature, an outdoor fan 8, and an outdoor piping temperature sensor 9 for detecting a piping temperature of the outdoor heat exchanger 5. The indoor unit 10 includes an indoor heat exchanger 3 and an indoor fan 7.

[0031] The compressor 1, the four-way valve 2, the indoor heat exchanger 3, the pressure reducing device 4, and the outdoor heat exchanger 5 are connected in series via a refrigerant circuit to define a heat pump refrigerating cycle. An electromagnetic expansion valve or a capillary tube is used as the pressure reducing device 4, and when the electromagnetic expansion valve is used, the pressure reducing device 4 is sometimes referred to as the "expansion valve 4".

[0032] Fig. 2 depicts a controller 12 for the indoor unit 10 and a controller 13 for the outdoor unit 11. The indoor controller 12 includes a defrosting start signal receiving section 60 and an indoor fan operating section 61 for operating the indoor fan 7 based on an output from the defrosting start signal receiving section 60. On the other hand, the outdoor controller 13 includes a defrosting start decision section 50, a compressor operating section 51 for controlling operation of the compressor 1 based on a temperature detected by the outdoor temperature sensor 6 and a temperature detected by the outdoor piping temperature sensor 9, both inputted to the defrosting start decision section 50, an expansion valve opening control section 52 for controlling an opening of the expansion valve 4, an outdoor fan operating section 53 for controlling operation of the outdoor fan 8, and a four-way valve switching section 54 for conducting a switching control of the four-way valve 2.

[0033] Fig. 3 is a flowchart indicating a control of the air conditioner according to the present invention during defrosting.

[0034] As shown in Fig. 3, a decision as to whether a defrosting operation is necessary is conducted based on a detection result of the outdoor piping temperature sensor 9. At step S1, the temperature detected by the outdoor piping temperature sensor 9 is compared with a first predetermined temperature (for example, -7°C) below a freezing point. If the detected temperature is less than the first predetermined temperature, a defrosting operation is conducted at step S2, but if the detected temperature is greater than or equal to the first predetermined temperature, the program returns to step S1.

[0035] It is to be noted that the first predetermined temperature is a temperature that is judged such that more than a predetermined amount of frost has been formed on the outdoor heat exchanger 5 and absorption of heat from the outdoor heat exchanger 5 is no longer possible.

[0036] At step S3, the temperature detected by the outdoor temperature sensor 6 is compared with a second predetermined temperature (for example, 1°C) higher than the first predetermined temperature referred to above. If the detected temperature is greater than or equal to the second predetermined temperature, a defrosting operation with use of atmospheric heat is conducted at step S4, but if the detected temperature is less than the second predetermined temperature, a defrosting operation by switching of the four-way valve is conducted at step S5.

[0037] The "defrosting operation with use of atmospheric heat" means a defrosting operation that is conducted using heat of outdoor air (atmospheric heat) under the condition in which the heating circuit is maintained without switching the four-way valve 2, and the "defrosting operation by switching of the four-way valve" means a defrosting operation that is conducted by switching the four-way valve 2 from the heating circuit to the cooling circuit to cause the refrigerant to flow in an opposite direction in the refrigerating cycle.

[0038] If the decision as to whether the defrosting operation is necessary is made based on only the detection result of the outdoor piping temperature sensor 9, it is

likely that the defrosting operation is frequently conducted when the outdoor temperature is low. For this reason, the decision as to whether the defrosting operation is necessary is made based on the detection result of the outdoor temperature sensor 6, a cumulative operation time period of the air conditioner, and the like, in addition to the detection result of the outdoor piping temperature sensor 9, thereby making it possible to minimize unnecessary defrosting operations.

(Embodiment 1)

[0039] Fig. 4 is a timing chart indicating a control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

[0040] In the outdoor controller 13, the defrosting start decision section 50 makes a defrosting start decision based on the temperature detected by the outdoor piping temperature sensor 9. When the defrosting start decision has been made, the compressor operating section 51, the expansion valve opening control section 52, the outdoor fan operating section 53, and the four-way valve switching section 54 conduct a control as shown in Fig. 4 to thereby conduct the defrosting operation.

[0041] At this moment, the defrosting start signal receiving section 60 in the indoor controller 12 receives a defrosting start signal from the outdoor controller 13, and the indoor fan operating section 61 also conducts the control as shown in Fig. 4 upon receipt of an output from the defrosting start signal receiving section 60.

[0042] During heating, when a decision to start the defrosting is made at time t1, the compressor 1 is stopped, and the speed of the outdoor fan 8 is maintained. At time t2, the defrosting operation is started to exchange heat between outdoor air and the outdoor heat exchanger 5 so that the defrosting may be conducted using heat of the outdoor air (atmospheric heat).

[0043] It is to be noted here that at time t1 the compressor 1 is stopped, but operation of the outdoor fan 8 is continued, and that the four-way valve 2 is not switched during the defrosting to maintain the heating circuit and not to cause the refrigerant to flow through the outdoor unit 11. Because no heating is conducted, the indoor fan 7 is stopped.

[0044] At time t2, it is preferred that the speed of the outdoor fan 8 be increased by the outdoor fan operating section 53 to a speed higher than a speed during the heating operation or a maximum speed. This is because frost evaporates more quickly, and the time period for defrosting can be shortened with an increase in speed of the outdoor fan 8. However, the speed of the outdoor fan 8 is not always increased.

[0045] The defrosting operation is terminated at time t3, and the refrigerating cycle returns to a state prior to the defrosting and subsequently to the normal heat pump heating operation at time t4. The time period (from time t2 to time t3) for the defrosting is set to a predetermined time period (about 12 minutes) within which it can be judged that frost will melt. However, because it can be judged that frost has melted if the temperature detected by the outdoor piping temperature sensor 9 is greater than a predetermined temperature (for example, 6°C), the defrosting operation may be terminated based on the temperature detected by the outdoor piping temperature sensor 9 in place of the aforementioned predetermined time period.

[0046] Although in this embodiment the operation frequency of the compressor 1 is varied, the defrosting operation is similarly conducted using a constant-speed compressor. The speed of the indoor fan 7 and that of the outdoor fan 8 may be fixed or varied.

[0047] Further, as shown in Fig. 4, the opening of the pressure reducing device (expansion valve) 4 is maintained constant and, hence, a capillary tube as well as the electromagnetic expansion valve can be used as the pressure reducing device 4.

[0048] The first and second predetermined temperatures may be set lower when first defrosting is conducted after the start of the heating operation and then set higher when subsequent defrosting is conducted. Alternatively, the first and second predetermined temperatures may be set lower during daytime heating and higher during nighttime heating. In this way, those temperatures can be varied depending on circumferential conditions.

[0049] The above-described control can melt frost adhering to the outdoor heat exchanger 5 using atmospheric heat and conduct the defrosting operation using an input of the outdoor fan 8 of about 100W, thus making it possible to enhance the defrosting efficiency.

[0050] The defrosting operation by switching of the four-way valve poses a problem that when frost melts, water generated thereby is discharged downwards from the outdoor unit 11, and if such water turns into ice at low outdoor temperatures, a man or woman may fall down on the ice or a drain hole or holes may clog with the ice. In this embodiment, however, because the defrosting operation with use of atmospheric heat is employed, frost having adhered to the outdoor heat exchanger 5 and having melted thereafter evaporates and scatters into the air by the action of the outdoor fan 8, such problem will not occur.

[0051] Also, during the defrosting operation by the outdoor heat exchanger 5, no heating operation is conducted, but the heat pump refrigerating cycle is maintained in a heating state. Accordingly, no cold refrigerant flows through the indoor unit 10 and, hence, remaining heat after the heating operation is retained in the indoor unit 10, and no chilly air comes out of the indoor unit 10. Further, because no refrigerant flows through the indoor unit 10 during the defrosting operation, no unpleasant refrigerant sound is generated.

[0052] If the speed of the outdoor fan 8 during the defrosting operation is set higher than that during the heating operation, a substantial amount of atmospheric heat passes through the outdoor heat exchanger 5 and quickly

melts frost adhering to the outdoor heat exchanger 5. Also, an increase in speed of the outdoor fan 8 increases the wind speed, and water into which frost has melted is blown off the outdoor unit 11 without adhering to a discharge portion of the outdoor unit 11 and, hence, no freezing occurs on the discharge portion.

(Embodiment 2)

[0053] Fig. 5 is a timing chart indicating another control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

[0054] The air conditioner according to this embodiment differs from the air conditioner according to the first embodiment referred to above in that an electromagnetic expansion valve or a capillary tube can be used as the pressure reducing device 4 in the first embodiment, while the electromagnetic expansion valve is used as the pressure reducing device 4 in this embodiment for control of the opening of the pressure reducing device 4. Also, in this embodiment, the expansion valve 4 is closed or the opening thereof is set to an opening (for example, less than 5% of a full opening) close to a fully closed state during the defrosting operation.

[0055] In this embodiment, the compressor 1, the indoor fan 7, and the outdoor fan 8 are stopped at time t1, and the expansion valve 4 is fully or almost fully closed at time t1 and then opened at time t3. However, operation of the compressor 1, the indoor fan 7, and the outdoor fan 8 after time t2 is the same as that in the first embodiment.

[0056] Although in this embodiment the expansion valve 4 is fully or almost fully closed at time t1, it may be closed at about time t2 at which the outdoor fan 8 is operated for the defrosting operation.

[0057] That is, when the outdoor fan 8 is operated for defrosting, movement of the refrigerant from the indoor unit 10 to the outdoor heat exchanger 5 can be avoided by setting the expansion valve 4 to a fully or almost fully closed state immediately before or after the defrosting operation. As a result, it becomes possible to minimize heat that is taken by the refrigerant present in the outdoor heat exchanger 5 and to efficiently make use of atmospheric heat to melt frost.

(Embodiment 3)

[0058] Fig. 6 is a timing chart indicating a further control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

[0059] The air conditioner according to this embodiment differs from the air conditioner according to the first embodiment in that in the former an electromagnetic expansion valve is used as the pressure reducing device 4, and the defrosting operation is conducted under the condition in which the compressor 1 is operated with a reduced frequency, and the closed state of the expansion valve 4 is continued for a predetermined time period, as shown in Fig. 6.

[0060] More specifically, at time t1, the indoor fan 7 and the outdoor fan 8 are stopped, and the compressor 1 is operated with a reduced frequency. At the same time, the expansion valve 4 is fully or almost fully closed. After the compressor 1 has been operated for a predetermined time period, it is stopped at time t2, and the defrosting operation is conducted by operating the outdoor fan 8 at a speed higher than that during heating.

[0061] Operation of the compressor 1, the indoor fan 7, and the outdoor fan 8 after time t2 is the same as that in the second embodiment.

[0062] By so setting, the refrigerant accumulated in the outdoor heat exchanger 5 is collected in the indoor unit 10 and accumulated in the indoor heat exchanger 3. As a result, it becomes possible to minimize heat that is taken by the refrigerant present in the outdoor heat exchanger 5 and efficiently make use of atmospheric heat to melt frost.

(Embodiment 4)

[0063] Fig. 7 is a timing chart indicating a still further control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

[0064] The air conditioner according to this embodiment differs from the air conditioner according to the first embodiment in that in the former, as shown in Fig. 7, an electromagnetic expansion valve is used as the pressure reducing device 4, and at time t1 at which a decision to start defrosting has been made, the expansion valve 4 is set to a fully or almost fully closed state, and the outdoor fan 8 is stopped, and in that the expansion valve 4 is subsequently controlled to, for example, a fully opened state at time t2 to cause heat remaining in the indoor unit 10 to flow through the outdoor heat exchanger 5 to thereby melt part of frost adhering to the outdoor heat exchanger 5. The defrosting operation is then started by closing the expansion valve 4 again and by operating the outdoor fan 8 at time t3.

[0065] Operation of the compressor 1, the expansion valve 4, the indoor fan 7, and the outdoor fan 8 after time t3 is the same as that in the second embodiment.

[0066] In general, at the beginning of the defrosting operation, frost adheres to a surface of the outdoor heat exchanger 5 without any space thereon. Accordingly, even if outdoor air is caused to flow through the outdoor heat exchanger 5 to melt the frost, the efficiency is low. Even in such a condition, the control of Fig. 7 can melt part of the frost adhering to the outdoor heat exchanger 5 by making use of heat after the heating to thereby form an airway or airways, through which outdoor air passes upon operation of the outdoor fan 8, thus making it possible to efficiently conduct the defrosting with use of atmospheric heat. Also, when the heat after the heating

flows through the outdoor heat exchanger 5, the heat makes it easy to separate the frost from fins of the outdoor heat exchanger 5, thus making it possible to shorten the time period for defrosting by the operation of the outdoor fan 8.

(Embodiment 5)

[0067] Fig. 8 is a timing chart indicating a yet further control operation of the air conditioner according to the present invention when the defrosting operation with use of atmospheric heat is conducted.

[0068] The air conditioner according to this embodiment differs from the air conditioner according to the first embodiment in that in the former, as shown in Fig. 8, an electromagnetic expansion valve is used as the pressure reducing device 4, and after the expansion valve 4 has been fully opened during heating, the defrosting operation is started by stopping the compressor 1 and by operating the outdoor fan 8.

[0069] More specifically, during heating, when a decision to start defrosting is made at time t1, the expansion valve 4 is set to, for example, a fully or almost fully opened state under the condition in which operation of the compressor 1 and the indoor fan 7 is continued, and the outdoor fan 8 is stopped. By so setting, heated refrigerant during heating is caused to flow through the outdoor heat exchanger 5 to melt part of frost. Thereafter, at time t2, the compressor 1 is stopped, and the expansion valve 4 is closed. At the same time, the speed of the outdoor fan 8 is increased to a speed higher than that during heating, and the indoor fan 7 is stopped.

[0070] Operation of the compressor 1, the expansion valve 4, the indoor fan 7, and the outdoor fan 8 after time t2 is the same as that in the second embodiment.

[0071] According to this embodiment, even if frost adheres to a front surface of the outdoor heat exchanger 5 without any space thereon, it becomes possible to melt part of the frost on the outdoor heat exchanger 5 by making use of heat after the heating to thereby form an airway or airways, through which outdoor air passes upon operation of the outdoor fan 8, thus making it possible to efficiently conduct the defrosting with use of atmospheric heat. Also, when the heat after the heating flows directly through the outdoor heat exchanger 5, the heat makes it easy to separate the frost from fins of the outdoor heat exchanger 5, thus making it possible to shorten the time period for defrosting by the operation of the outdoor fan 8.

(Embodiment 6)

[0072] Fig. 9 is a timing chart indicating a control operation of the air conditioner according to the present invention when a defrosting operation is conducted by switching a four-way valve. In this embodiment, an electromagnetic expansion valve is used as the pressure reducing device 4, and the defrosting operation by switching of the four-way valve and the defrosting operation with use of atmospheric heat are both employed as explained later.

[0073] As shown in Fig. 9, at time t1 during heating, the defrosting start decision section 50 of the outdoor controller 13 makes a decision to start defrosting. If the temperature detected by the outdoor temperature sensor 6 is less than the second predetermined temperature, the operation frequency of the compressor 1 is reduced, and the four-way valve 2 is switched to the cooling circuit for defrosting. At the same time, the outdoor fan 8 and the indoor fan 7 are stopped, and the expansion valve 4 is closed to about half of an opening during heating.

[0074] At time t2, the frequency of the compressor 1 is increased, and the expansion valve 4 is opened to an opening between the opening during heating and an opening during the defrosting operation by switching of the four-way valve. At time t3, the compressor 1 is stopped to terminate the defrosting operation by switching of the four-way valve, and the outdoor fan 8 is operated to conduct the defrosting operation with use of atmospheric heat.

[0075] In the defrosting operation with use of atmospheric heat upon operation of the outdoor fan 8, the expansion valve 4 is set to a fully or almost fully closed state, the stopped state of the indoor fan 7 is maintained, and the four-way valve 2 retains the cooling circuit. In this event, operation of the outdoor fan 8 is started, but it is preferred that the speed of the outdoor fan 8 be increased to a speed higher than that during heating or a maximum speed by the outdoor fan operating section 53. However, the speed of the outdoor fan 8 may be set to the speed during heating.

[0076] The defrosting operation is terminated at time t4, and the refrigerating cycle returns to a state prior to the defrosting operation and subsequently to the normal heat pump heating operation at time t5.

[0077] If a time period during which the heat pump refrigerating cycle is being set to the cooling circuit upon switching of the four-way valve 2 is limited to a predetermined time period or less, the defrosting operation by switching of the four-way valve can efficiently melt part of frost adhering to the outdoor heat exchanger 5 within a short time period.

[0078] Even if sufficient defrosting has not been attained, an airway or airways through which outdoor air passes during the defrosting operation by the outdoor fan 8 are positively formed, thus making it possible to conduct an efficient defrosting operation with use of atmospheric heat. If the refrigerating cycle is switched, when the outdoor piping temperature sensor 9 has detected a third predetermined temperature higher than the first predetermined temperature, from the defrosting operation by switching of the four-way valve to the defrosting operation with use of atmospheric heat, the refrigerating cycle can be transferred to the defrosting operation with use of atmospheric heat, which is conducted by the outdoor fan 8, within a short time period without conducting the defrosting operation by switching of the four-way

valve more than necessary (up to a high temperature), thus enhancing the efficiency of the defrosting operation.

[0079] Although in the above-described embodiment the defrosting operation with use of atmospheric heat is conducted when the temperature detected by the outdoor temperature sensor 6 is greater than or equal to the second predetermined temperature (for example, 1°C), the time period for operation of the outdoor fan 8 can be set shorter when the temperature detected by the outdoor temperature sensor 6 is greater than or equal to a fourth predetermined temperature (for example, 5°C) higher than the second predetermined temperature than when the outdoor temperature is less than the fourth predetermined temperature. This is because when the outdoor temperature is high, the quantity of atmospheric heat is large, which makes it possible to melt frost adhering to the outdoor heat exchanger 5 within a shorter time period. As a result, the time period for the defrosting operation can be shortened.

Industrial Applicability

[0080] As described above, the air conditioner according to the present invention can conduct defrosting using atmospheric heat without changing component formations of general air conditioners, and can be accordingly used for large air conditioning systems as well as air conditioners for home use.

[0081] List of Reference Numerals

1	compressor
2	four-way valve
3	indoor heat exchanger
4	pressure reducing device
5	outdoor heat exchanger
6	outdoor temperature sensor
7	indoor fan
8	outdoor fan
9	outdoor piping temperature sensor
10	indoor unit
11	outdoor unit
12	indoor controller
13	outdoor controller
50	defrosting start decision section
51	compressor operating section
52	expansion valve opening control section
53	outdoor fan operating section
54	four-way valve switching section
60	defrosting start signal receiving section
61	indoor fan operating section

Claims

1. An air conditioner having a compressor, a four-way valve, an indoor heat exchanger, a pressure reducing device, and an outdoor heat exchanger, all connected in series via a refrigerant circuit to define a heat pump refrigerating cycle, the air conditioner comprising:

an indoor fan for exchanging heat between the indoor heat exchanger and indoor air;
an outdoor fan for exchanging heat between the outdoor heat exchanger and outdoor air; and
an outdoor temperature sensor for detecting an outdoor temperature,
wherein when the outdoor temperature detected by the outdoor temperature sensor is greater than or equal to a predetermined temperature, the compressor is stopped, and the outdoor fan is operated to defrost the outdoor heat exchanger.

2. The air conditioner according to claim 1, wherein the heat pump refrigerating cycle is held in a heating state during a defrosting operation for the outdoor heat exchanger.

3. The air conditioner according to claim 1 or 2, wherein a speed of the outdoor fan during the defrosting operation is set to a speed higher than that during a heating operation or a maximum speed.

4. The air conditioner according to any one of claims 1 to 3, wherein an expansion valve is used as the pressure reducing device, and the expansion valve is fully or almost fully closed immediately before or after the defrosting operation.

5. The air conditioner according to any one of claims 1 to 3, wherein an expansion valve is used as the pressure reducing device, and before the defrosting operation is conducted, an operation frequency of the compressor is reduced, and the expansion valve is subsequently fully or almost fully closed, and wherein after the compressor has been operated for a predetermined time period, the compressor is stopped, and the outdoor fan is operated.

6. The air conditioner according to any one of claims 1 to 3, wherein an expansion valve is used as the pressure reducing device, and before the defrosting operation is conducted, the expansion valve is fully or almost fully closed, and wherein the expansion valve is subsequently opened for a predetermined time period, and the outdoor fan is operated.

7. The air conditioner according to any one of claims 1 to 3, wherein an expansion valve is used as the pressure reducing device, and before the defrosting operation is conducted, the outdoor fan is stopped, and the expansion valve is fully or almost fully opened, and wherein upon operation of a predetermined time period, the compressor is stopped, and the outdoor fan is operated.

8. An air conditioner having a compressor, a four-way valve, an indoor heat exchanger, an expansion valve, and an outdoor heat exchanger, all connected in series via a refrigerant circuit to define a heat pump refrigerating cycle, the air conditioner comprising:

an indoor fan for exchanging heat between the indoor heat exchanger and indoor air;
an outdoor fan for exchanging heat between the outdoor heat exchanger and outdoor air; and
an outdoor temperature sensor for detecting an outdoor temperature,
wherein when the outdoor temperature detected by the outdoor temperature sensor is less than a predetermined temperature, the heat pump refrigerating cycle is switched to a cooling circuit by the four-way valve, the compressor is subsequently stopped, the expansion valve is fully or almost fully closed, and the outdoor fan is operated to defrost the outdoor heat exchanger.

9. The air conditioner according to claim 8, wherein a time period during which the heat pump refrigerating cycle is being set to the cooling circuit upon switching of the four-way valve is limited to a predetermined time period or less.

10. The air conditioner according to claim 8, further comprising an outdoor piping temperature sensor for detecting an outdoor piping temperature, wherein when the outdoor piping temperature detected by the outdoor piping temperature sensor is less than a predetermined temperature, the heat pump refrigerating cycle is switched to the cooling circuit by the four-way valve.

11. The air conditioner according to any one of claims 1 to 10, wherein when the outdoor temperature detected by the outdoor temperature sensor is greater than or equal to a predetermined temperature, a time period for operation of the outdoor fan is set shorter than when the outdoor temperature is less than the predetermined temperature.

Fig.1

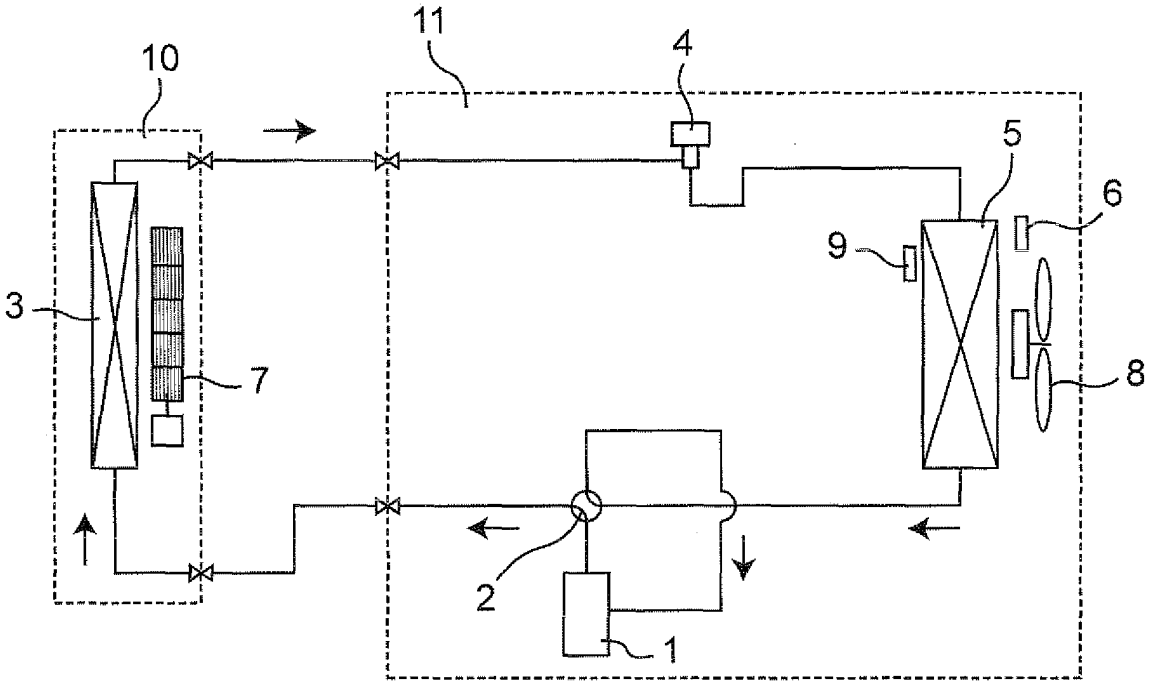


Fig.2

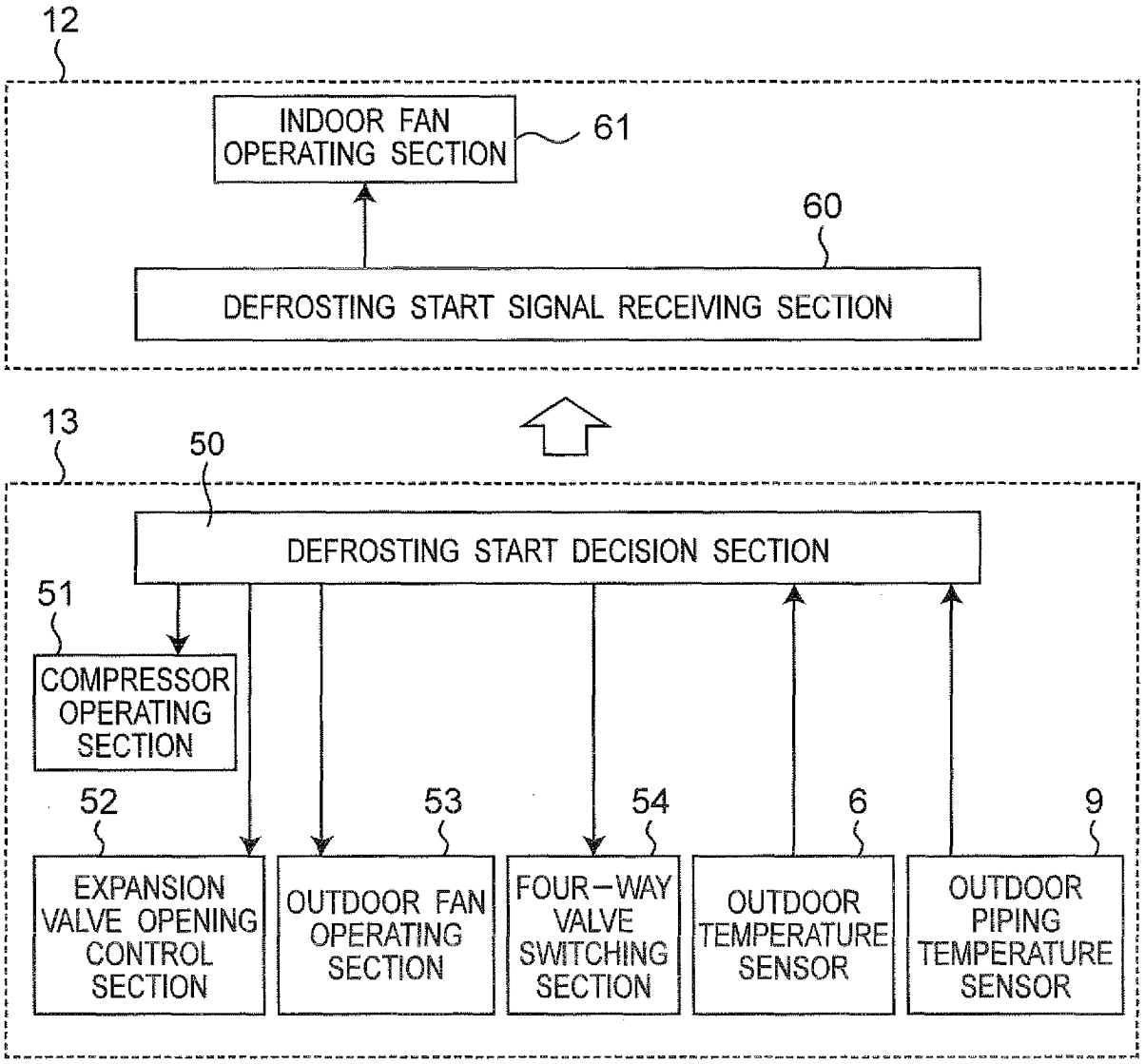

12
INDOOR FAN OPERATING SECTION
61
60
DEFROSTING START SIGNAL RECEIVING SECTION
13
50
DEFROSTING START DECISION SECTION
51
COMPRESSOR OPERATING SECTION
52
53
54
6
9
EXPANSION VALVE OPENING CONTROL SECTION
OUTDOOR FAN OPERATING SECTION
FOUR-WAY VALVE SWITCHING SECTION
OUTDOOR TEMPERATURE SENSOR
OUTDOOR PIPING TEMPERATURE SENSOR

Fig.3

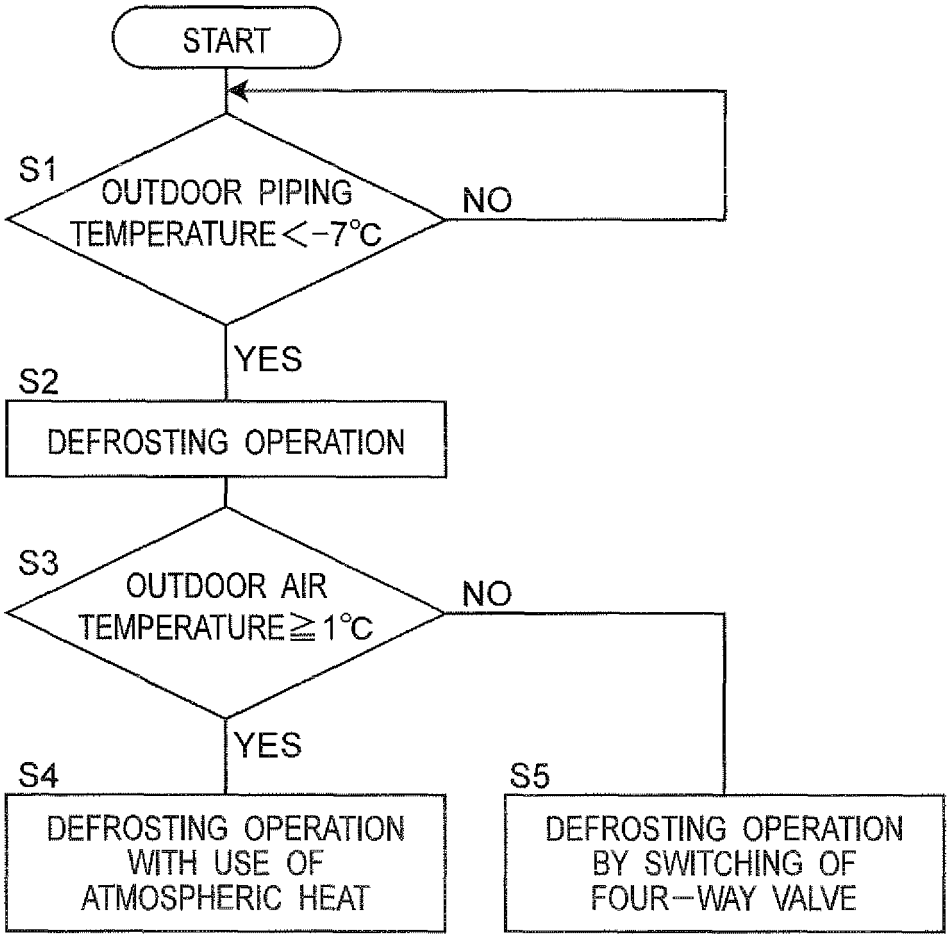

START
S1
OUTDOOR PIPING TEMPERATURE < −7°C
NO
YES
S2
DEFROSTING OPERATION
S3
OUTDOOR AIR TEMPERATURE ≧ 1°C
NO
YES
S4
DEFROSTING OPERATION WITH USE OF ATMOSPHERIC HEAT
S5
DEFROSTING OPERATION BY SWITCHING OF FOUR−WAY VALVE

Fig.4

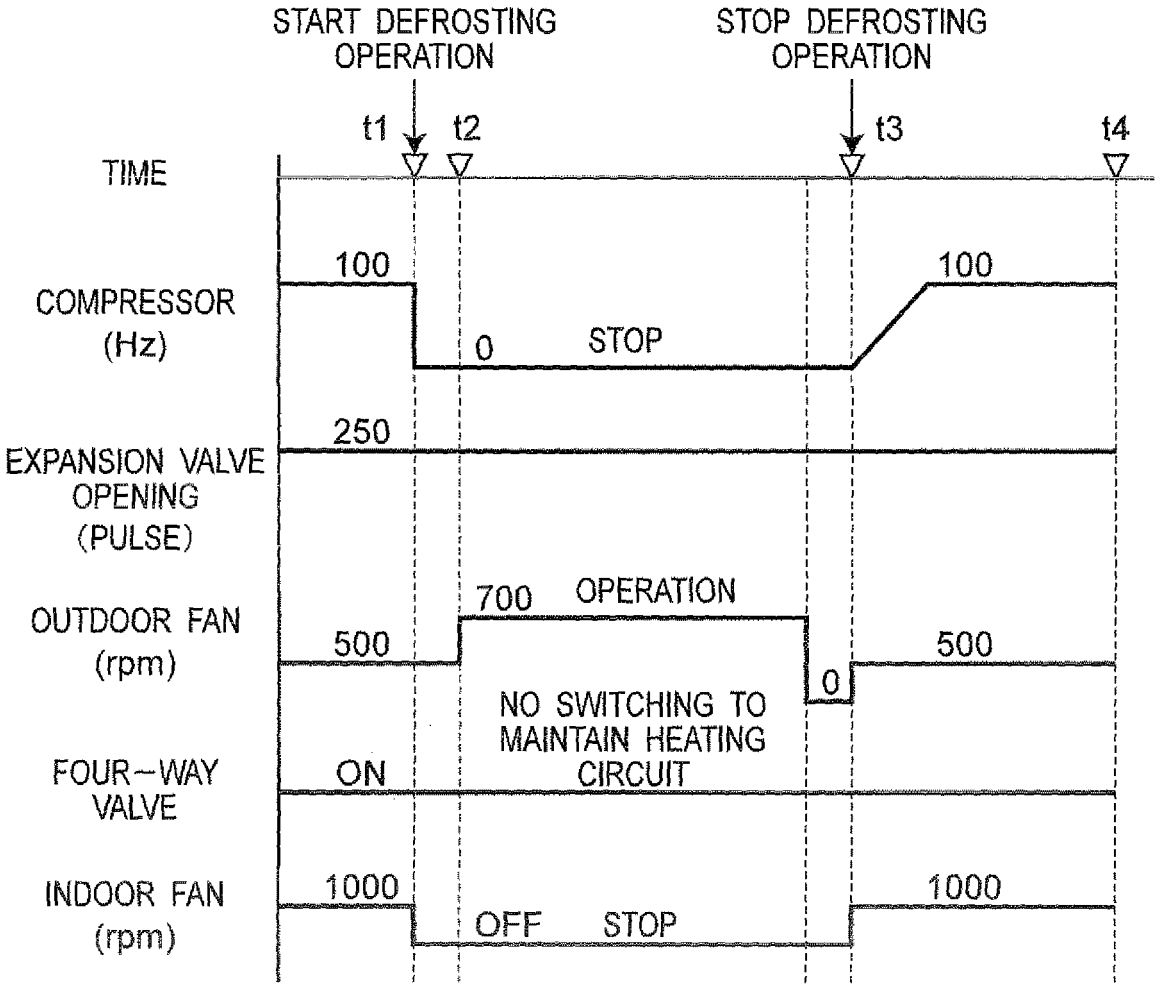

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
TIME
COMPRESSOR (Hz)
100
0
STOP
100
EXPANSION VALVE OPENING (PULSE)
250
OUTDOOR FAN (rpm)
700
OPERATION
500
500
0
NO SWITCHING TO MAINTAIN HEATING CIRCUIT
FOUR-WAY VALVE
ON
INDOOR FAN (rpm)
1000
OFF
STOP
1000

Fig.5

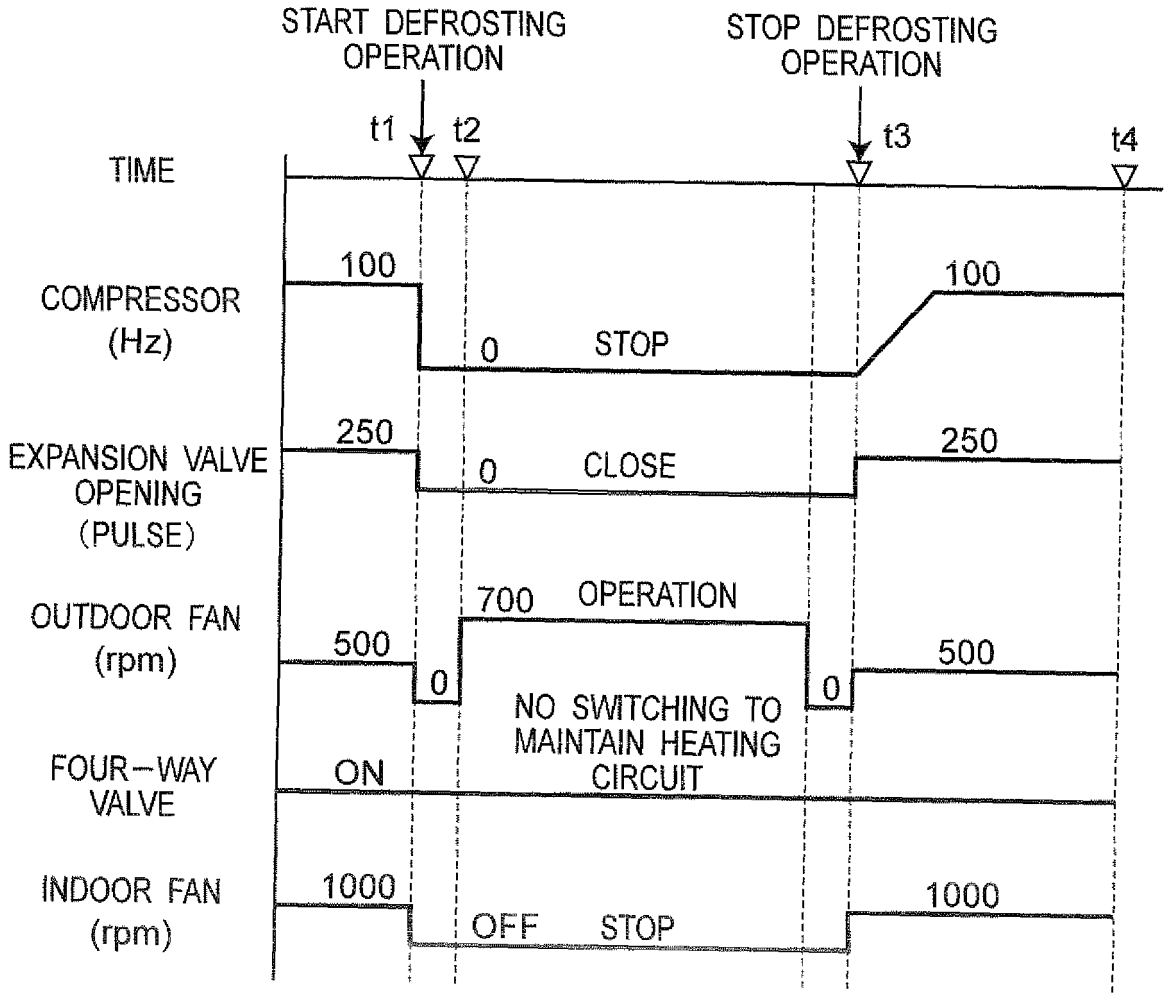

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
TIME
COMPRESSOR (Hz)
100
0
STOP
100
EXPANSION VALVE OPENING (PULSE)
250
0
CLOSE
250
OUTDOOR FAN (rpm)
500
0
700
OPERATION
0
500
NO SWITCHING TO MAINTAIN HEATING CIRCUIT
FOUR-WAY VALVE
ON
INDOOR FAN (rpm)
1000
OFF
STOP
1000

Fig.6

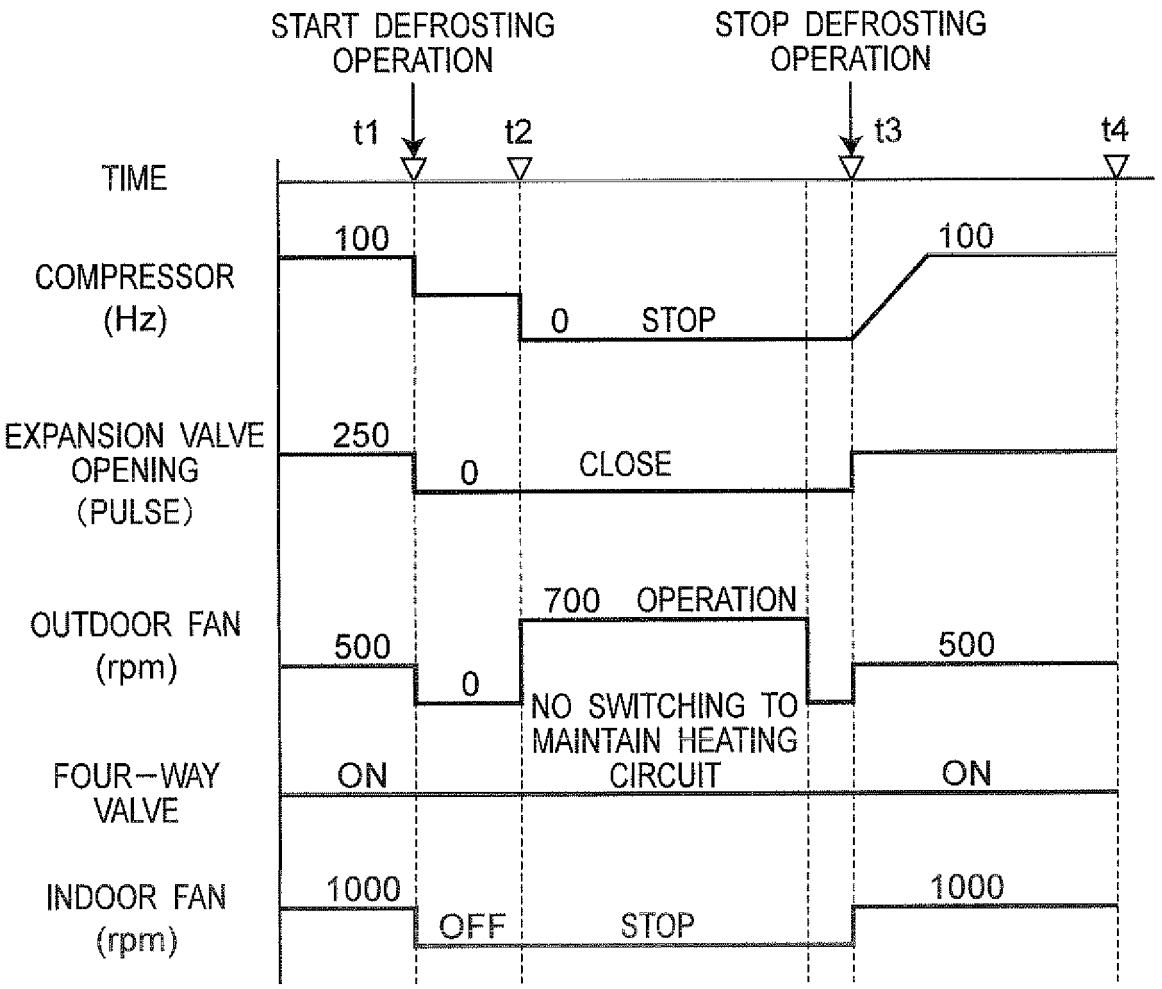

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
TIME
COMPRESSOR (Hz)
100
0
STOP
100
EXPANSION VALVE OPENING (PULSE)
250
0
CLOSE
OUTDOOR FAN (rpm)
500
0
700 OPERATION
NO SWITCHING TO MAINTAIN HEATING CIRCUIT
500
FOUR-WAY VALVE
ON
ON
INDOOR FAN (rpm)
1000
OFF
STOP
1000

Fig.7

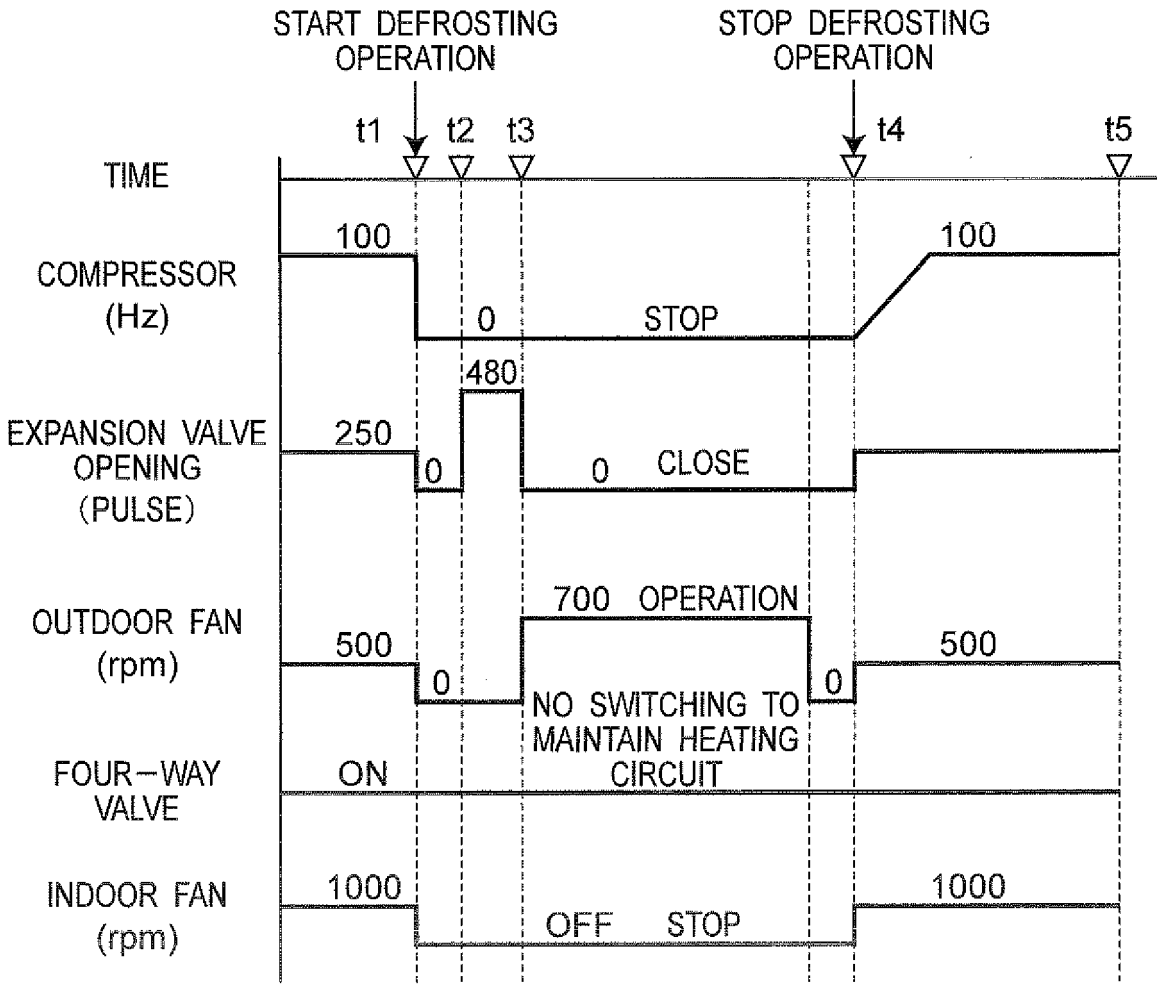

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
t5
TIME
COMPRESSOR (Hz)
100
0
STOP
100
EXPANSION VALVE OPENING (PULSE)
250
0
480
0
CLOSE
OUTDOOR FAN (rpm)
500
0
700
OPERATION
NO SWITCHING TO MAINTAIN HEATING CIRCUIT
0
500
FOUR-WAY VALVE
ON
INDOOR FAN (rpm)
1000
OFF
STOP
1000

Fig.8

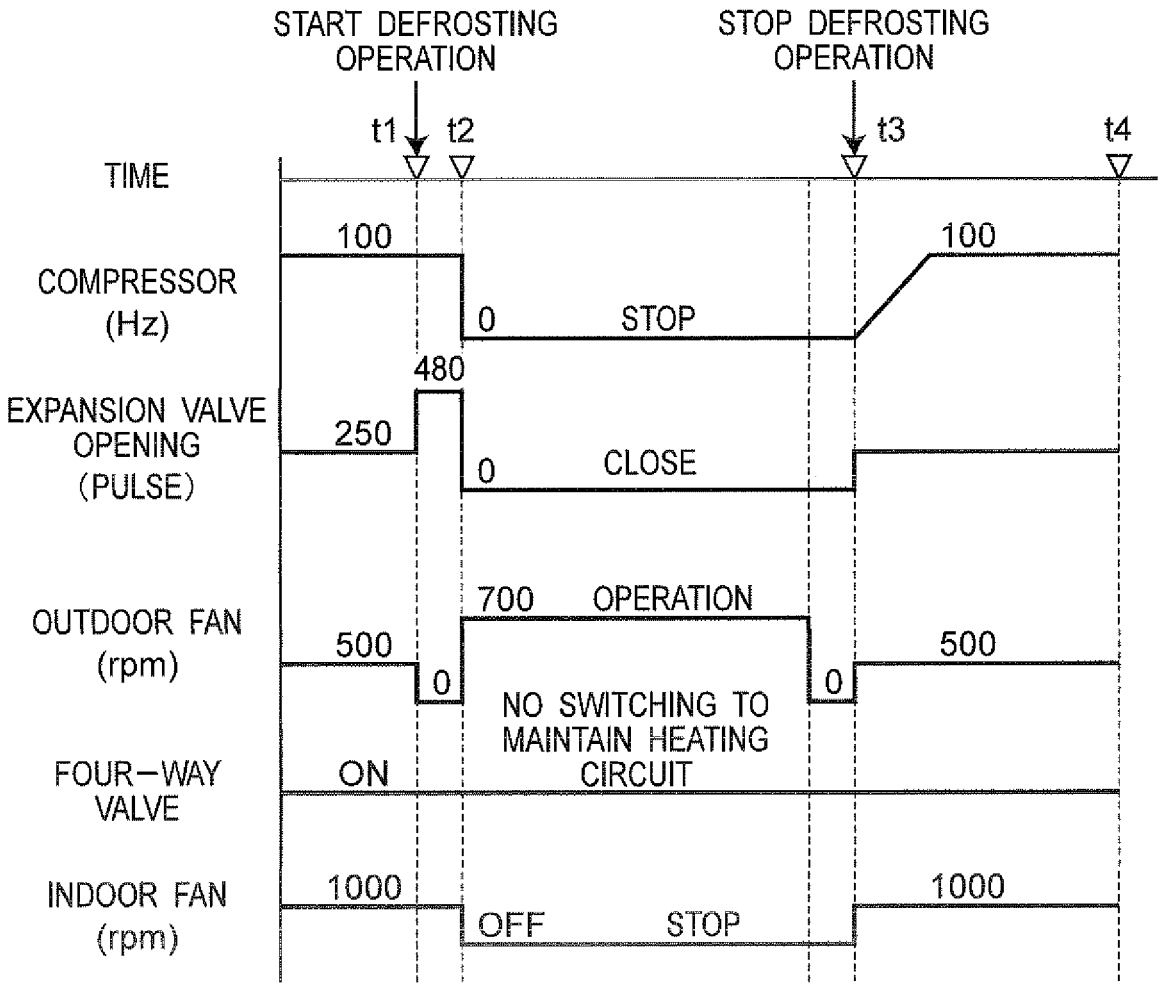

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
TIME
COMPRESSOR (Hz)
100
0
STOP
100
EXPANSION VALVE OPENING (PULSE)
480
250
0
CLOSE
OUTDOOR FAN (rpm)
700
OPERATION
500
0
0
500
NO SWITCHING TO MAINTAIN HEATING CIRCUIT
FOUR-WAY VALVE
ON
INDOOR FAN (rpm)
1000
OFF
STOP
1000

Fig.9

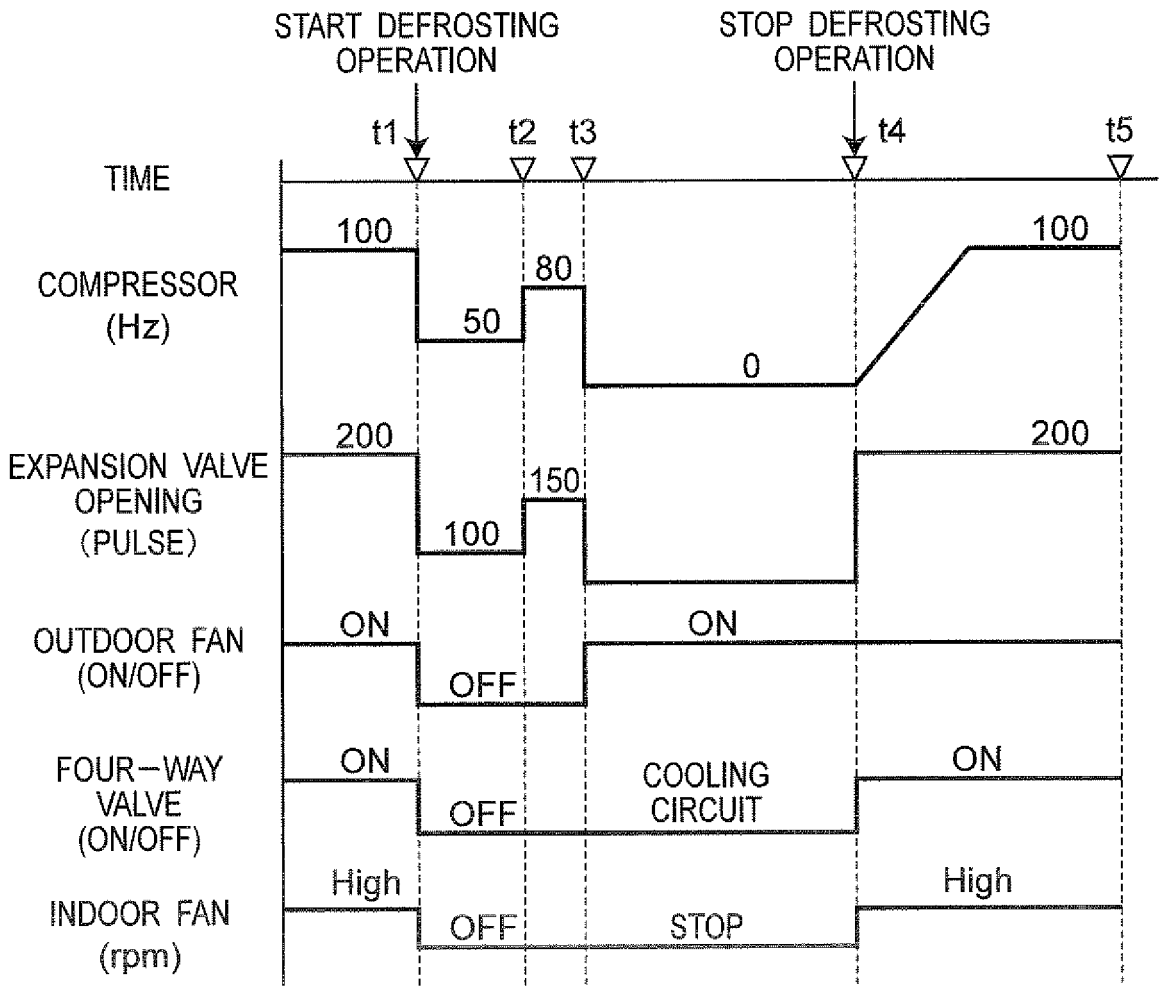

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
t5
TIME
COMPRESSOR (Hz)
100
50
80
0
100
EXPANSION VALVE OPENING (PULSE)
200
100
150
200
OUTDOOR FAN (ON/OFF)
ON
OFF
ON
FOUR-WAY VALVE (ON/OFF)
ON
OFF
COOLING CIRCUIT
ON
INDOOR FAN (rpm)
High
OFF
STOP
High

Fig.10

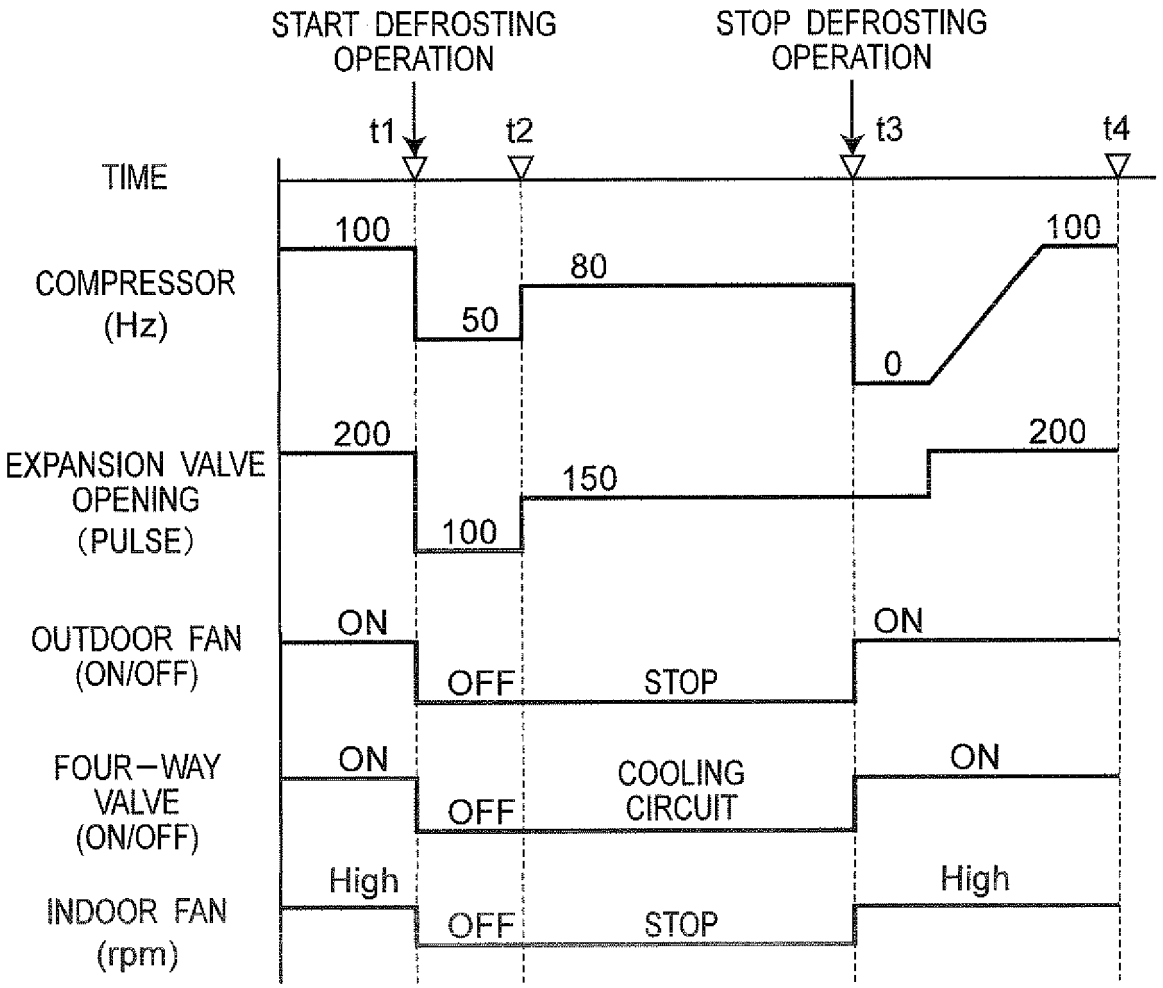
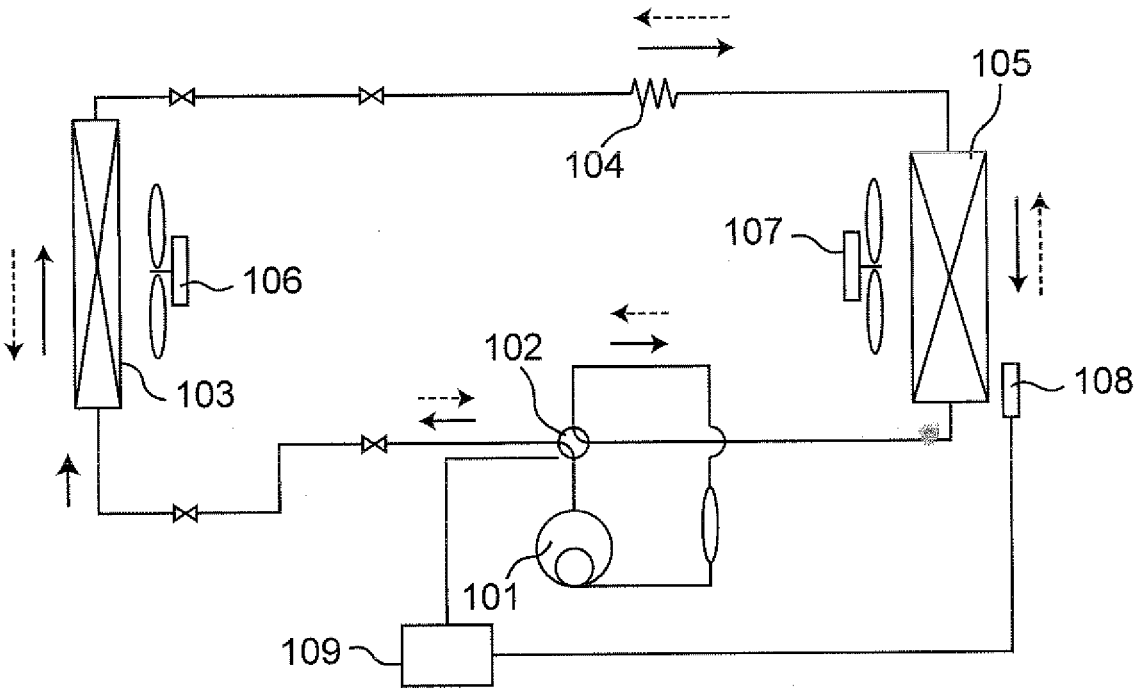

START DEFROSTING OPERATION
STOP DEFROSTING OPERATION
t1
t2
t3
t4
TIME
COMPRESSOR (Hz)
100
50
80
0
100
EXPANSION VALVE OPENING (PULSE)
200
100
150
200
OUTDOOR FAN (ON/OFF)
ON
OFF
STOP
ON
FOUR-WAY VALVE (ON/OFF)
ON
OFF
COOLING CIRCUIT
ON
INDOOR FAN (rpm)
High
OFF
STOP
High

Fig.11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004591

A. CLASSIFICATION OF SUBJECT MATTER
F24F11/02(2006.01)i, *F25B47/02*(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)
F24F11/02, F25B47/02

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 1996-2009
Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009

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 59-195045 A (Toshiba Corp.), 06 November 1984 (06.11.1984), entire text; fig. 1 to 4 (Family: none)	1,2 3,7-10 4-6,11
Y	JP 2007-232327 A (Sharp Corp.), 13 September 2007 (13.09.2007), claim 1; paragraphs [0007] to [0010] (Family: none)	3
Y	JP 10-115477 A (Daikin Industries, Ltd.), 06 May 1998 (06.05.1998), paragraphs [0003], [0005] to [0010]; fig. 1 to 4 (Family: none)	7,8

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 December, 2009 (08.12.09)	15 December, 2009 (15.12.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004591

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 6-272932 A (Fujitsu General Ltd.), 27 September 1994 (27.09.1994), claim 1; paragraphs [0001] to [0005] (Family: none)	9
Y	JP 4-217763 A (Daikin Industries, Ltd.), 07 August 1992 (07.08.1992), paragraphs [0008] to [0011], [0019]; fig. 1, 2 (Family: none)	10
Y	JP 3-95339 A (Daikin Industries, Ltd.), 19 April 1991 (19.04.1991), claim 1; fig. 1, 2 (Family: none)	10
A	JP 62-94751 A (Matsushita Seiko Co., Ltd.), 01 May 1987 (01.05.1987), entire text; fig. 1 to 2 (Family: none)	1-11
A	JP 7-43051 A (Toshiba Corp.), 10 February 1995 (10.02.1995), paragraphs [0007] to [0017] (Family: none)	1-11
A	JP 2006-226568 A (Matsushita Electric Industrial Co., Ltd.), 31 August 2006 (31.08.2006), claim 1; paragraph [0014] (Family: none)	1-11

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004591

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The technical feature common to the inventions of claims 1-11 relates to that "during defrosting, a compressor is stopped and an outdoor fan is rotated to perform defrosting." However, the search has revealed that the technical feature is disclosed in a prior art document (JP 59-195045 A cited in the report) and makes no contribution over the prior art. Thus, the technical feature cannot be a special technical feature within the meaning of PCT Rule 13.2, second sentence.

Accordingly, the inventions of claims 1-11 do not satisfy the requirement of unity of invention.

(Continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004591

Continuation of Box No.III of continuation of first sheet(2)

[1] The invention of claim 8 is described in the independent format and does not refer to the invention of claim 1. However, as shown in [4] below, an inventive step was searched by considering that the invention of claim 8 defines a control operation when the temperature condition of the defrosting operation in the invention of claim 1 is not satisfied. The same applied to the inventions of claims 9-11 referring to claim 8.

[2] Claim 10 contains a phrase of "the aforementioned outdoor piping temperature." However, no "outdoor piping temperature" is described before the phrase. It is unclear what is indicated by "the aforementioned." Accordingly, an inventive step was searched by considering that "the aforementioned" is absent.

[3] Claim 10 describes a new condition that "when the outdoor piping temperature is below a predetermined temperature." However, claim 10 refers to claim 8 containing a temperature condition that "when the outdoor temperature is below a predetermined temperature." It is unclear whether both of the conditions should be satisfied or only one of the two conditions should be satisfied. If both of the two conditions should be satisfied, the invention of claim 10 includes the case that the control operation defined in claim 8 is not executed even if the condition in claim 8 which claim 10 refers to is satisfied. This contradicts with the invention of claim 8.

[4] The invention of claim 11 specifies a control operation "to operate the outdoor fan" when the condition that "the outdoor temperature is below a predetermined value", which is different from the condition in the invention of claim 1 referred to, is satisfied. However, claim 1 to which claim 11 refers does not define any control operation when the condition that "the outdoor temperature is below a predetermined value" is satisfied. Similarly, the invention of claim 11 defines a control operation "to operate an outdoor fan" when the condition that "the outdoor temperature is above or equal to a predetermined value" which is different from the condition in the invention of claim 8 which is referred to. However, claim 8 does not specify any control operation to be performed when the condition that "the outdoor temperature is above or equal to a predetermined value" is satisfied. If the control operation is "operation of the outdoor fan," it is unclear between the control operations to be performed when the condition of claim 1 or claim 8 is satisfied and not satisfied.

In order to establish different conditions, the invention of claim 8 should refer to claim 1 and the invention of claim 11 should refer to claim 8 or claims 9 and 10 which refer to claim 8.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 60133249 A **[0009]**