(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 361 190 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
15.08.2018 Bulletin 2018/33

(21) Application number: **16885082.4**

(22) Date of filing: **12.12.2016**

(51) Int Cl.:
F25B 49/02 *(2006.01)* ***F25B 1/00*** *(2006.01)*

(86) International application number:
PCT/JP2016/086936

(87) International publication number:
WO 2017/122479 (20.07.2017 Gazette 2017/29)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **14.01.2016 JP 2016005401**

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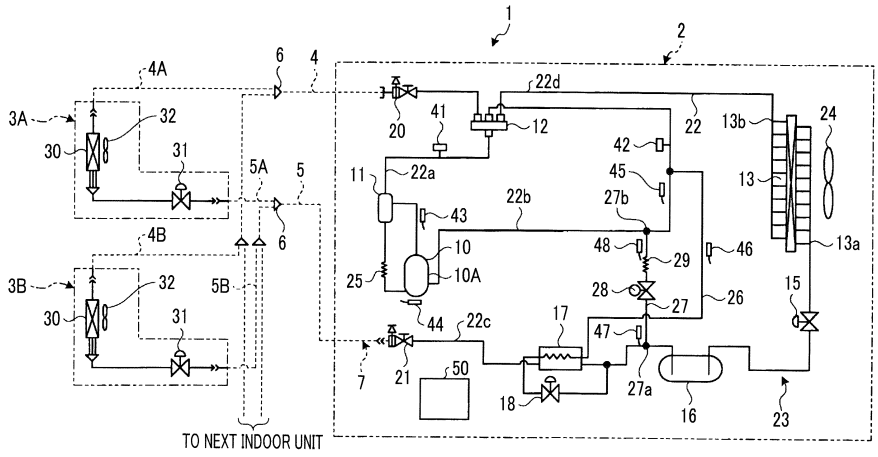
(54) REFRIGERATION CYCLE DEVICE AND CONTROL METHOD FOR DETERMINATION OF LEAKS IN BYPASS VALVE OF REFRIGERATION CYCLE DEVICE

(57) This refrigeration cycle device is equipped with: a bypass pipe 27 which has one end 27a that is connected to an outdoor side liquid pipe 22c between an outdoor heat exchanger 13 and indoor heat exchangers 30 and another end 27b that is connected to a suction pipe 22b of a compressor 10; a bypass valve 28 which controls the flow of a refrigerant in the bypass pipe 27; a floodback determination unit which determines the presence or absence of floodback of the refrigerant to the compressor 10; and a bypass valve leakage determination unit which determines whether or not the floodback has been caused by leaks in the bypass valve 28 on the basis of the suction superheat degree of the refrigerant obtained in the suction pipe 22b upstream of the other end 27b of the bypass pipe 27.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a refrigeration cycle device in which a compressor, a condenser, an expansion valve, and an evaporator are connected to one another by piping, and a control method for determination of leaks in a bypass valve of a refrigeration cycle device.

Background Art

[0002] In the related art, a refrigeration cycle device having a configuration in which a compressor which compresses a refrigerant, a condenser which cools and condenses the compressed gas refrigerant, an expansion valve which decompresses and expands the condensed liquid refrigerant, and an evaporator which heats and evaporates the decompressed liquid refrigerant are connected by piping is known (refer to, for example, PTL 1).

Citation List

Patent Literature

[0003] [PTL 1] Japanese Unexamined Patent Application Publication No. 2008-112322

Summary of Invention

Technical Problem

[0004] In this type of refrigeration cycle device, in order to avoid excessive rise in the refrigerant discharge temperature of the compressor or the temperature inside a casing of the compressor, a configuration having a bypass pipe which bypasses the evaporator from a liquid pipe between the condenser and the evaporator and returns the liquid refrigerant to a suction pipe of the compressor, and a bypass valve which controls the flow of the refrigerant in the bypass pipe is assumed.

[0005] Incidentally, in the configuration described above, in a case where the refrigerant discharge temperature of the compressor or the temperature inside the casing of the compressor rises to a temperature equal to or higher than a predetermined temperature, the temperature rise is suppressed by opening the bypass valve and returning an appropriate amount of liquid refrigerant to the compressor. For this reason, in a case where leakage occurs in the bypass valve, a large amount of liquid refrigerant is returned to the compressor, whereby liquid flooding occurs, and thus there is a concern that the compressor may be damaged. However, in a case where the liquid flooding to the compressor has occurred, it is difficult to determine whether or not the cause of the liquid flooding is leakage in the bypass valve.

[0006] The present invention has been made in view of the above circumstances and has an object to provide a refrigeration cycle device in which whether or not liquid flooding to a compressor is caused by leakage in a bypass valve can be easily determined, and a control method for determination of leaks in a bypass valve of a refrigeration cycle device.

Solution to Problem

[0007] In order to solve the above-described problem and achieve the object, according to an aspect of the present invention, there is provided a refrigeration cycle device in which a compressor, a condenser, an expansion valve, and an evaporator are connected to one another by piping, the refrigeration cycle device including: a bypass pipe that has one end connected to a liquid pipe between the condenser and the evaporator and the other end connected to a suction pipe of the compressor, and bypasses the evaporator; a bypass valve that controls a flow of a refrigerant in the bypass pipe; a liquid flooding determination unit that determines presence or absence of liquid flooding of the refrigerant to the compressor; and a bypass valve leakage determination unit that determines whether or not the liquid flooding is caused by leakage in the bypass valve, based on a first suction superheat degree of the refrigerant acquired further on the upstream side than the other end of the bypass pipe in the suction pipe.

[0008] According to this configuration, the bypass valve leakage determination unit that determines whether or not the liquid flooding is caused by leakage in the bypass valve, based on a first suction superheat degree of the refrigerant acquired further on the upstream side than the other end of the bypass pipe in the suction pipe, is provided, and therefore, it is possible to easily determine whether or not the liquid flooding to the compressor is caused by leakage in the bypass valve.

[0009] In this configuration, the liquid flooding determination unit may determine that the liquid flooding has occurred, in a case where a second suction superheat degree of the refrigerant acquired at a bottom portion of a casing of the compressor or a discharge superheat degree of the refrigerant which is discharged from the compressor has become equal to or lower than each predetermined reference value determined in advance. According to this configuration, the presence or absence of the liquid flooding to the compressor can be determined with a simple configuration.

[0010] Further, the bypass pipe may include a throttle mechanism which is disposed between the bypass valve and the other end, an inlet temperature sensor which is disposed between the bypass valve and the one end, and an outlet temperature sensor which is disposed between the throttle mechanism and the other end. According to this configuration, for example, even in a case where the liquid flooding has occurred due to the liquid refrigerant which has not completely evaporated in the evaporator, it is possible to accurately determine the

presence or absence of leakage in the bypass valve.

[0011] Further, in a case where it is determined that the liquid flooding is caused by leakage in the bypass valve, an opening and closing operation of the bypass valve may be repeatedly executed. According to this configuration, in a case where the cause of the leakage in the bypass valve is temporary foreign matter biting, the foreign matter is removed by the opening and closing operation. For this reason, the leakage in the bypass valve can be easily eliminated.

[0012] Further, in a case where it is determined that the liquid flooding is not caused by leakage in the bypass valve, an operation of the compressor may be stopped and an abnormality warning may be issued. According to this configuration, it is possible to perform service inspection of the refrigeration cycle device while preventing damage to the compressor.

[0013] Further, according to another aspect of the present invention, there is provided a control method for determination of leaks in a bypass valve of a refrigeration cycle device in which a compressor, a condenser, an expansion valve, and an evaporator are connected to one another by piping and which has a bypass pipe having one end connected to a liquid pipe between the condenser and the evaporator and the other end connected to a suction pipe of the compressor, and bypassing the evaporator, and a bypass valve that controls a flow of a refrigerant in the bypass pipe, the method including: a liquid flooding determination step of determining presence or absence of liquid flooding of the refrigerant to the compressor; and a bypass valve leakage determination step of determining whether or not the liquid flooding is caused by leakage in the bypass valve, based on a first suction superheat degree of the refrigerant acquired further on the upstream side than the other end of the bypass pipe in the suction pipe.

Advantageous Effects of Invention

[0014] According to the present invention, the bypass valve leakage determination unit that determines whether or not the liquid flooding is caused by leakage in the bypass valve, based on a first suction superheat degree of the refrigerant acquired further on the upstream side than the other end of the bypass pipe in the suction pipe, is provided, and therefore, it is possible to easily determine whether or not the liquid flooding to the compressor is caused by leakage in the bypass valve.

Brief Description of Drawings

[0015]

Fig. 1 is a circuit configuration diagram of an air conditioner according to the present embodiment.

Fig. 2 is a block diagram showing a functional configuration of a control device.

Description of Embodiments

[0016] Hereinafter, an embodiment of the present invention will be described in detail based on the drawings. The present invention is not limited by this embodiment. Further, constituent elements which can be easily replaced by those skilled in the art, or substantially the same constituent elements are included in the constituent elements in the embodiment. Further, the constituent elements described below can be appropriately combined. In this embodiment, an air conditioner will be described as an example of a refrigeration cycle device.

[0017] Fig. 1 is a circuit configuration diagram of an air conditioner according to this embodiment. An air conditioner (a refrigeration cycle device) 1 is a so-called multi-type air conditioner which is configured to include a single outdoor unit 2 and a plurality of (in Fig. 1, two) indoor units 3A and 3B. The plurality of indoor units 3A and 3B are connected in parallel to each other through a branching unit 6 between a gas pipe 4 and a liquid pipe 5 which are connected to the outdoor unit 2.

[0018] The outdoor unit 2 is provided with an inverter-driven compressor 10 that compresses a refrigerant, an oil separator 11 that separates lubricating oil from a refrigerant gas, a four-way valve 12 that switches a circulation direction of the refrigerant, an outdoor heat exchanger (an evaporator or a condenser) 13 that performs heat exchange between the refrigerant and the outside air, an outdoor expansion valve (an expansion valve) 15 that is used at the time of heating to decompress and expand the refrigerant, a receiver 16 that stores a liquid refrigerant, a supercooling heat exchanger 17 that provides supercooling to the liquid refrigerant, a supercooling expansion valve 18 that controls the amount of refrigerant which is diverted to the supercooling heat exchanger 17, a gas-side operation valve 20, and a liquid-side operation valve 21. Further, the outdoor unit 2 is provided with a control device 50 that controls the operation of the entire air conditioner 1.

[0019] The above respective devices on the outdoor unit 2 side are sequentially connected through a refrigerant pipe 22 to configure an outdoor-side refrigerant circuit 23. More specifically, the refrigerant pipe 22 is provided with a discharge pipe 22a which connects the discharge side of the compressor 10 and the four-way valve 12, and a suction pipe 22b which connects the suction side of the compressor 10 and the four-way valve 12. Further, the refrigerant pipe 22 is configured to include an outdoor-side liquid pipe (a liquid pipe between the condenser and the evaporator) 22c which connects one end 13a of the outdoor heat exchanger 13 and the liquid-side operation valve 21, and an outdoor-side gas pipe 22d which connects the other end 13b of the outdoor heat exchanger 13 and the four-way valve 12.

[0020] Further, the outdoor unit 2 is provided with an outdoor fan 24 which blows the outside air to the outdoor heat exchanger 13. Further, an oil return circuit 25 for returning the lubricating oil separated from a discharge

refrigerant gas in the oil separator 11 to the compressor 10 side by a predetermined amount is provided between the oil separator 11 and the suction pipe 22b of the compressor 10. The supercooling expansion valve 18 is provided in a branch liquid pipe 26 branched from the outdoor-side liquid pipe 22c, and the branch liquid pipe 26 is connected to the suction pipe 22b through the supercooling heat exchanger 17.

[0021] Further, the outdoor unit 2 is provided with a bypass pipe 27 that connects the outdoor-side liquid pipe 22c and the suction pipe 22b, and a bypass valve 28 and a capillary (a throttle mechanism) 29 provided in the bypass pipe 27. In the bypass pipe 27, in a case where a refrigerant discharge temperature of the compressor 10 or a temperature inside a casing of the compressor 10 rises to a temperature equal to or higher than a predetermined temperature, the bypass valve 28 is opened to return an appropriate amount of liquid refrigerant to the compressor 10, thereby suppressing a temperature rise. The bypass pipe 27 has one end 27a connected to the outdoor-side liquid pipe 22c between the receiver 16 and the supercooling heat exchanger 17, and the other end 27b connected to the suction pipe 22b between the compressor 10 and the branch liquid pipe 26. The bypass valve 28 is an on-off valve that controls the flow of the refrigerant in the bypass pipe 27. The capillary 29 is a thin tube for depressurizing the refrigerant and is provided between the bypass valve 28 and the other end 27b of the bypass pipe 27.

[0022] In this embodiment, various pressure sensors or temperature sensors are provided in the outdoor-side refrigerant circuit 23. Specifically, a high-pressure sensor 41 for detecting the pressure of the high-pressure refrigerant discharged from the compressor 10 is provided in the discharge pipe 22a between the compressor 10 and the four-way valve 12, and a low-pressure sensor 42 for detecting the pressure of the low-pressure refrigerant that is suctioned into the compressor 10 is provided in the suction pipe 22b between the four-way valve 12 and the branch liquid pipe 26.

[0023] Further, a discharge temperature sensor 43 for detecting the temperature of the discharged refrigerant is provided in the discharge pipe 22a between the compressor 10 and the oil separator 11, and a casing temperature sensor 44 for detecting the temperature of the refrigerant suctioned into a casing 10A is provided at a bottom portion of the casing 10A of the compressor 10. Further, a suction temperature sensor 45 for detecting the temperature of the low-pressure refrigerant that is suctioned into the compressor 10 is provided in the suction pipe 22b between the branch liquid pipe 26 and the compressor 10, and a supercooling coil temperature sensor 46 for detecting the temperature of the refrigerant flowing through the branch liquid pipe 26 is provided in the branch liquid pipe 26. Further, in the bypass pipe 27, an inlet temperature sensor 47 is provided between one end 27a of the bypass pipe 27 and the bypass valve 28, and an outlet temperature sensor 48 is provided between the other end 27b of the bypass pipe 27 and the capillary 29.

[0024] The gas pipe 4 and the liquid pipe 5 are refrigerant pipes which are connected to the gas-side operation valve 20 and the liquid-side operation valve 21 of the outdoor unit 2, and the piping lengths thereof are appropriately set according to the distance between the outdoor unit 2 and the plurality of indoor units 3A and 3B which are connected to the outdoor unit 2, at the time of installation on site. A plurality of branching units 6 are provided in the middle of the gas pipe 4 and the liquid pipe 5, and an appropriate number of indoor units 3A and 3B are connected through the branching units 6. Accordingly, a sealed one refrigeration cycle (refrigerant circuit) 7 is configured.

[0025] Each of the indoor units 3A and 3B has an indoor heat exchanger (an evaporator or a condenser) 30 which cools or heats indoor air through heat exchange between the indoor air and the refrigerant to provide it for indoor air conditioning, an indoor expansion valve (an expansion valve) 31 which is used at the time of cooling, and an indoor fan 32 which circulates the indoor air through the indoor heat exchanger 30, and the indoor units 3A and 3B are connected to the branching units 6 through branch gas pipes 4A and 4B and branch liquid pipes 5A and 5B on the indoor side.

[0026] In the air conditioner 1 described above, a cooling operation is performed as follows. The lubricating oil included in the refrigerant is separated from the high-temperature and high-pressure refrigerant gas compressed by and discharged from the compressor 10, in the oil separator 11. Thereafter, the refrigerant gas is circulated toward the outdoor heat exchanger 13 side by the four-way valve 12, and subjected to heat exchange with the outside air which is blown by the outdoor fan 24 in the outdoor heat exchanger 13, thereby being condensed and liquefied. The liquid refrigerant passes through the outdoor expansion valve 15 and is temporarily stored in the receiver 16.

[0027] The liquid refrigerant having a circulation amount adjusted by the receiver 16 is partially diverted from the outdoor-side liquid pipe 22c in the course of passing through the supercooling heat exchanger 17 and is subjected to heat exchange with the refrigerant adiabatically expanded in the supercooling expansion valve 18, thereby being supercooled. This liquid refrigerant is led from the outdoor unit 2 to the liquid pipe 5 via the liquid-side operation valve 21 and diverted to the branch liquid pipes 5A and 5B of the indoor units 3A and 3B through the branching units 6. On the other hand, the refrigerant used for supercooling flows into the suction pipe 22b of the compressor 10 through the branch liquid pipe 26.

[0028] The liquid refrigerants diverted to the branch liquid pipes 5A and 5B flow into the respective indoor units 3A and 3B, are adiabatically expanded in the indoor expansion valves 31, respectively, and flow into the indoor heat exchangers 30 as gas-liquid two-phase flows.

In the indoor heat exchanger 30, the indoor air which is circulated by the indoor fan 32 is subjected to heat exchange with the refrigerant to be cooled and is provided for the cooling of the indoor. On the other hand, the refrigerant evaporates to be gasified, reaches the branching unit 6 through each of the branch gas pipes 4A and 4B, and joins the refrigerant gas from another indoor unit at the gas pipe 4.

[0029] The refrigerant gas which has joined at the gas pipe 4 returns to the outdoor unit 2 again, passes through the gas-side operation valve 20 and the four-way valve 12, joins the refrigerant gas from the supercooling heat exchanger 17, and is then suctioned into the compressor 10. This refrigerant is compressed again in the compressor 10, and the cooling operation is performed by repeating the above cycle. During the cooling operation described above, the outdoor heat exchanger 13 functions as a condenser and the indoor heat exchanger 30 functions as an evaporator.

[0030] On the other hand, a heating operation is performed as follows. The lubricating oil included in the refrigerant is separated from the high-temperature and high-pressure refrigerant gas compressed by and discharged from the compressor 10, in the oil separator 11, and the high-temperature and high-pressure refrigerant gas is then circulated toward the gas-side operation valve 20 side through the four-way valve 12. The high-pressure gas refrigerant is led out from the outdoor unit 2 via the gas-side operation valve 20 and the gas pipe 4 and is introduced into the plurality of indoor units 3A and 3B via the branching units 6 and the branch gas pipes 4A and 4B on the indoor side.

[0031] The high-temperature and high-pressure refrigerant gas introduced into each of the indoor units 3A and 3B is subjected to heat exchange with the indoor air which is circulated through the indoor fan 32 in the indoor heat exchangers 30, and the indoor air heated in this way is blown into the room to be provided for heating. On the other hand, the refrigerant condensed and liquefied in the indoor heat exchanger 30 reaches the branching unit 6 via the indoor expansion valve 31 and each of the branch liquid pipes 5A and 5B, joins the refrigerant from another indoor unit, and returns to the outdoor unit 2 via the liquid pipe 5. During the heating, in each of the indoor units 3A and 3B, the degree of opening of the indoor expansion valve 31 is controlled such that the refrigerant outlet temperature of the indoor heat exchanger 30 functioning as a condenser or the refrigerant supercooling degree reaches a control target value.

[0032] The refrigerant which has returned to the outdoor unit 2 reaches the supercooling heat exchanger 17 via the liquid-side operation valve 21, is supercooled similar to the case of the cooling, and then flows into the receiver 16 to be temporarily stored therein, whereby the circulation amount is adjusted. This liquid refrigerant is supplied to the outdoor expansion valve 15 to be adiabatically expanded, and then flows into the outdoor heat exchanger 13.

[0033] In the outdoor heat exchanger 13, the outside air which is blown from the outdoor fan 24 and the refrigerant perform heat exchange, and thus the refrigerant absorbs heat from the outside air and is evaporated and gasified. This refrigerant passes through the four-way valve 12 from the outdoor heat exchanger 13, joins the refrigerant gas from the supercooling heat exchanger 17, is then suctioned into the compressor 10, and is compressed again in the compressor 10. The heating operation is performed by repeating the above cycle.

[0034] During the cooling operation or the heating operation described above, in a case where the refrigerant discharge temperature of the compressor 10, which is detected by the discharge temperature sensor 43, becomes equal to or higher than a predetermined temperature (for example, 115°C), or the temperature inside the casing 10A of the compressor 10, which is detected by the casing temperature sensor 44, becomes equal to or higher than a predetermined temperature (for example 75°C), the control device 50 opens the bypass valve 28 under a predetermined condition to cause the liquid refrigerant to flow from the outdoor-side liquid pipe 22c into the suction pipe 22b through the bypass pipe 27. This liquid refrigerant evaporates in the suction pipe 22b, thereby cooling the refrigerant which is suctioned into the compressor 10, and the compressor 10.

[0035] Incidentally, in the configuration described above, in a case where leakage occurs in the bypass valve 28, a large amount of liquid refrigerant is suctioned into the compressor 10, whereby liquid flooding occurs and thus there is a concern that the compressor 10 may be damaged. As the cause of the liquid flooding, in addition to a case where leakage occurs in the bypass valve 28, a case where the refrigerant which has not sufficiently evaporated in the outdoor heat exchanger 13 or the indoor heat exchanger 30 as an evaporator is returned through the suction pipe 22b, or a case where the refrigerant which has not sufficiently evaporated in the supercooling heat exchanger 17 is returned through the suction pipe 22b is considered. In general, in a case where the liquid flooding occurs, since the operation of the compressor 10 (the air conditioner 1) is stopped and the service and inspection by a serviceman is then performed, it is important to determine in advance whether or not the liquid flooding is caused by leakage in the bypass valve 28. However, in a case where the liquid flooding to the compressor 10 occurs, it is difficult to determine whether or not the cause of the liquid flooding is the leakage in the bypass valve 28.

[0036] Fig. 2 is a block diagram showing a functional configuration of the control device. As shown in Fig. 2, the control device 50 is provided with a control unit 51, a superheat degree calculation unit 52, a liquid flooding determination unit 53, a bypass valve leakage determination unit 54, and an interface unit 55. The bypass valve 28, the high-pressure sensor 41, the low-pressure sensor 42, the discharge temperature sensor 43, the casing temperature sensor 44, the suction temperature sensor 45,

the supercooling coil temperature sensor 46, the inlet temperature sensor 47, the outlet temperature sensor 48, and an information unit 49 are connected to the interface unit 55. The information unit 49 is, for example, a buzzer, a lamp, or the like and is an alarm device which issues an abnormality warning that the liquid flooding has occurred.

[0037] The control unit 51 controls liquid flooding determination processing and bypass valve leakage determination processing and also controls the operation of the entire air conditioner 1. The superheat degree calculation unit 52 calculates the superheat degree of the refrigerant from the pressure and the temperature of the refrigerant during the operation of the compressor 10 and in a state where the bypass valve 28 is closed, at a plurality of locations of the outdoor-side refrigerant circuit 23. Specifically, the superheat degree calculation unit 52 calculates a discharge superheat degree T1 of the refrigerant from the deviation between the refrigerant discharge temperature which is detected by the discharge temperature sensor 43 and the saturation temperature of the discharge pressure of the refrigerant, which is detected by the high-pressure sensor 41. Further, the superheat degree calculation unit 52 calculates a casing superheat degree (a second suction superheat degree) T2 of the refrigerant from the deviation between the temperature inside the casing of the refrigerant, which is detected by the casing temperature sensor 44, and the saturation temperature of the suction pressure of the refrigerant, which is detected by the low-pressure sensor 42. Then, the superheat degree calculation unit 52 outputs the calculated discharge superheat degree T1 and the calculated casing superheat degree T2 to the liquid flooding determination unit 53.

[0038] Further, the superheat degree calculation unit 52 calculates a suction superheat degree (a first suction superheat degree) T3 of the refrigerant from the difference between the suction temperature of the refrigerant, which is detected by the suction temperature sensor 45, and the saturation temperature of the suction pressure of the refrigerant, which is detected by the low-pressure sensor 42. Then, the superheat degree calculation unit 52 outputs the calculated suction superheat degree T3 to the bypass valve leakage determination unit 54.

[0039] The liquid flooding determination unit 53 determines whether or not the liquid flooding has occurred in the compressor 10, based on the acquired discharge superheat degree T1 or the acquired casing superheat degree T2. Specifically the liquid flooding determination unit 53 compares the discharge superheat degree T1 with a predetermined discharge superheat degree reference value (reference value) $T1_S$ set in advance, and determines that the liquid flooding has occurred, if the discharge superheat degree T1 is equal to or lower than the discharge superheat degree reference value $T1_S$ (for example, 15°C), and determines that the liquid flooding has not occurred, if the discharge superheat degree T1 is not equal to or lower than the discharge superheat degree reference value $T1_S$. Similarly, the liquid flooding determination unit 53 compares the casing superheat degree T2 with a predetermined casing superheat degree reference value (reference value) $T2_S$ set in advance, and determines that the liquid flooding has occurred, if the casing superheat degree T2 is equal to or lower than the casing superheat degree reference value $T2_S$ (for example, 10°C), and determines that the liquid flooding has not occurred, if the casing superheat degree T2 is not equal to or lower than the casing superheat degree reference value $T2_S$. Each of the reference values $T1_S$ and $T2_S$ can be appropriately changed. Further, the liquid flooding determination unit 53 may determine whether or not the liquid flooding has occurred, by using at least one of the discharge superheat degree T1 and the casing superheat degree T2. However, by using the superheat degrees of the refrigerant on both the discharge side and the suction side, it is possible to more accurately determine the presence or absence of the occurrence of the liquid flooding.

[0040] The bypass valve leakage determination unit 54 determines whether or not the liquid flooding is caused by the leakage in the bypass valve 28, based on the acquired suction superheat degree T3, in a case where the liquid flooding has occurred. Specifically, the bypass valve leakage determination unit 54 compares the suction superheat degree T3 with a predetermined suction superheat degree reference value (reference value) $T3_S$ set in advance. In this case, if the suction superheat degree T3 is equal to or higher than the suction superheat degree reference value $T3_S$ (for example, 10°C), the liquid flooding in the suction pipe 22b which is located further on the upstream side than the bypass pipe 27 has not occurred. For this reason, the bypass valve leakage determination unit 54 determines that the liquid flooding is caused by the leakage in the bypass valve 28. Further, if the suction superheat degree T3 is not equal to or higher than the suction superheat degree reference value $T3_S$, the liquid flooding has already occurred in the suction pipe 22b which is located further on the upstream side than the bypass pipe 27. For this reason, the bypass valve leakage determination unit 54 determines that the liquid flooding is not caused only by the leakage in the bypass valve 28.

[0041] Here, in a case where the liquid flooding has already occurred in the suction pipe 22b which is located further on the upstream side than the bypass pipe 27, it is difficult to determine even whether or not leakage has actually occurred in the bypass valve 28. For this reason, in this configuration, the bypass valve leakage determination unit 54 obtains an inlet/outlet temperature difference T4 from the refrigerant inlet temperature and the refrigerant outlet temperature which are respectively detected by the inlet temperature sensor 47 and the outlet temperature sensor 48 provided in the bypass pipe 27, and determines the presence or absence of the leakage in the bypass valve 28, based on the inlet/outlet temperature difference T4. If the inlet/outlet temperature differ-

ence T4 is equal to or higher than a predetermined inlet/outlet temperature difference reference value $T4_S$ (for example, 5°C), a possibility that the refrigerant may flow through the bypass pipe 27 is high, and thus the bypass valve leakage determination unit 54 determines that leakage occurs in the bypass valve 28. Further, if the inlet/outlet temperature difference T4 is not equal to or higher than the predetermined inlet/outlet temperature difference reference value $T4_S$, the bypass valve leakage determination unit 54 determines that there is no leakage in the bypass valve 28. In this manner, the inlet temperature sensor 47 and the outlet temperature sensor 48 are provided in the bypass pipe 27, and the presence or absence of the leakage in the bypass valve 28 can be accurately determined by the value of the inlet/outlet temperature difference T4 detected by the inlet temperature sensor 47 and the outlet temperature sensor 48.

[0042] In a case where it is determined that the liquid flooding is caused by the leakage in the bypass valve 28, the control unit 51 repeats an opening and closing operation to sequentially close, open, and close the bypass valve 28 by multiple times (for example, three times). It is empirically known that the leakage in the bypass valve 28 sometimes occurs, for example, due to foreign matter being temporarily bitten between a valve body and a valve seat (not shown). For this reason, the foreign matter is removed by repeating the opening and closing operation of the bypass valve 28, and therefore, it is possible to eliminate the liquid flooding without requiring the service and inspection by a serviceman.

[0043] On the other hand, in a case where it is determined that the liquid flooding is not caused by the leakage in the bypass valve 28 or that the liquid flooding is not caused only by the leakage in the bypass valve 28, the control unit 51 stops the compressor 10 and issues an abnormality warning through the information unit 49. In this case, the liquid flooding occurs due to the refrigerant which has not sufficiently evaporated in the outdoor heat exchanger 13 or the indoor heat exchanger 30 as an evaporator being returned through the suction pipe 22b, or the refrigerant which has not sufficiently evaporated in the supercooling heat exchanger 17 being returned through the suction pipe 22b. For this reason, by stopping the operation of the compressor 10 (the air conditioner 1), it is possible to perform the service and inspection by a serviceman while reliably preventing damage to the compressor.

[0044] As described above, according to this embodiment, the bypass pipe 27 having one end 27a connected to the outdoor-side liquid pipe 22c between the outdoor heat exchanger 13 and the indoor heat exchanger 30 and the other end 27b connected to the suction pipe 22b of the compressor 10, the bypass valve 28 that controls the flow of the refrigerant in the bypass pipe 27, the liquid flooding determination unit 53 that determines the presence or absence of the liquid flooding of the refrigerant to the compressor 10, and the bypass valve leakage determination unit 54 that determines whether or not the liquid flooding is caused by the leakage in the bypass valve 28, based on the suction superheat degree T3 of the refrigerant acquired further on the upstream side than the other end 27b of the bypass pipe 27 in the suction pipe 22b are provided, and therefore, it is possible to easily determine whether or not the liquid flooding to the compressor 10 is caused by the leakage in the bypass valve 28.

[0045] Further, according to this embodiment, the liquid flooding determination unit 53 is configured to determine that the liquid flooding has occurred, in a case where at least one of the casing superheat degree T2 of the refrigerant acquired at the bottom portion of the casing 10A of the compressor 10 and the discharge superheat degree T1 of the refrigerant which is discharged from the compressor 10 is equal to or lower than the predetermined casing superheat degree reference value $T2_S$ or the discharge superheat degree reference value $T1_S$ determined in advance. Therefore, the presence or absence of the liquid flooding to the compressor 10 can be determined with a simple configuration.

[0046] Further, according to this embodiment, the bypass pipe 27 is provided with the capillary 29 which is disposed between the other end 27b of the bypass pipe 27 and the bypass valve 28, the inlet temperature sensor 47 which is disposed between one end 27a of the bypass pipe 27 and the bypass valve 28, and the outlet temperature sensor 48 which is disposed between the other end 27b of the bypass pipe 27 and the capillary 29, and therefore, for example, even in a case where the liquid flooding has occurred due to the liquid refrigerant which has not completely evaporated in the outdoor heat exchanger 13, the presence or absence of the leakage in the bypass valve 28 can be accurately determined based on the comparison between the inlet/outlet temperature difference T4 detected by the inlet temperature sensor 47 and the outlet temperature sensor 48 and the inlet/outlet temperature difference reference value $T4_S$.

[0047] Further, according to this embodiment, in a case where it is determined that the liquid flooding is caused by the leakage in the bypass valve 28, the control to repeatedly execute the opening and closing operation of the bypass valve 28 is performed, and therefore, in a case where the cause of the leakage in the bypass valve 28 is temporary foreign matter biting, the foreign matter is removed by the opening and closing operation. For this reason, it is possible to easily eliminate the leakage in the bypass valve 28.

[0048] Further, according to this embodiment, in a case where it is determined that the liquid flooding is not caused by the leakage in the bypass valve 28, the operation of the compressor 10 is stopped and the control to issue an abnormality warning through the information unit 49 is performed, and therefore, it is possible to perform the service and inspection of the refrigeration cycle device while preventing damage to the compressor 10.

[0049] An embodiment of the present invention has been described above. However, this embodiment has

been presented as an example and is not intended to limit the scope of the invention. This embodiment can be implemented in various other forms, and various omissions, substitutions, and changes can be made within a scope which does not depart from the gist of the invention. This embodiment or the modifications thereof are included in the scope or the gist of the invention and likewise included in the invention described in the claims and the equivalent scope thereof. In this embodiment, the air conditioner 1 has been described as an example of the refrigeration cycle device. However, the refrigeration cycle device may be a refrigeration device which is disposed in a freezing storage warehouse, as long as it has a heat exchanger functioning as an evaporator and a condenser.

Reference Signs List

[0050]

1: air conditioner (refrigeration cycle device)
2: outdoor unit
3A, 3B: indoor unit
10: compressor
10A: casing
12: four-way valve
13: outdoor heat exchanger (evaporator, condenser)
15: outdoor expansion valve (expansion valve)
17: supercooling heat exchanger
18: supercooling expansion valve
22: refrigerant pipe
22a: discharge pipe
22b: suction pipe
22c: outdoor-side liquid pipe (liquid pipe between condenser and evaporator)
22d: outdoor-side gas pipe
23: outdoor-side refrigerant circuit
26: branch liquid pipe
27: bypass pipe
27a: one end
27b: the other end
28: bypass valve
29: capillary (throttle mechanism)
30: indoor heat exchanger (evaporator, condenser)
31: indoor expansion valve (expansion valve)
41: high-pressure sensor
42: low-pressure sensor
43: discharge temperature sensor
44: casing temperature sensor
45: suction temperature sensor
46: supercooling coil temperature sensor
47: inlet temperature sensor
48: outlet temperature sensor
49: information unit
50: control device
51: control unit
52: superheat degree calculation unit
53: liquid flooding determination unit
54: bypass valve leakage determination unit
55: interface unit
T1: discharge superheat degree
$T1_S$: discharge superheat degree reference value (reference value)
T2: casing superheat degree (second suction superheat degree)
$T2_S$: casing superheat degree reference value (reference value)
T3: suction superheat degree (first suction superheat degree)
$T3_S$: suction superheat degree reference value (reference value)
T4: inlet/outlet temperature difference
$T4_S$: inlet/outlet temperature difference reference value

Claims

1. A refrigeration cycle device in which a compressor, a condenser, an expansion valve, and an evaporator are connected to one another by piping, the device comprising:

a bypass pipe that has one end connected to a liquid pipe between the condenser and the evaporator and the other end connected to a suction pipe of the compressor, and bypasses the evaporator;
a bypass valve that controls a flow of a refrigerant in the bypass pipe;
a liquid flooding determination unit that determines presence or absence of liquid flooding of the refrigerant to the compressor; and
a bypass valve leakage determination unit that determines whether or not the liquid flooding is caused by leakage in the bypass valve, based on a first suction superheat degree of the refrigerant acquired further on the upstream side than the other end of the bypass pipe in the suction pipe.

2. The refrigeration cycle device according to claim 1, wherein the liquid flooding determination unit determines that the liquid flooding has occurred, in a case where a second suction superheat degree of the refrigerant acquired at a bottom portion of a casing of the compressor or a discharge superheat degree of the refrigerant which is discharged from the compressor has become equal to or lower than each predetermined reference value determined in advance.

3. The refrigeration cycle device according to claim 1 or 2, wherein the bypass pipe includes a throttle mechanism which is disposed between the bypass valve and the other end, an inlet temperature sensor which is disposed between the bypass valve and the

one end, and an outlet temperature sensor which is disposed between the throttle mechanism and the other end.

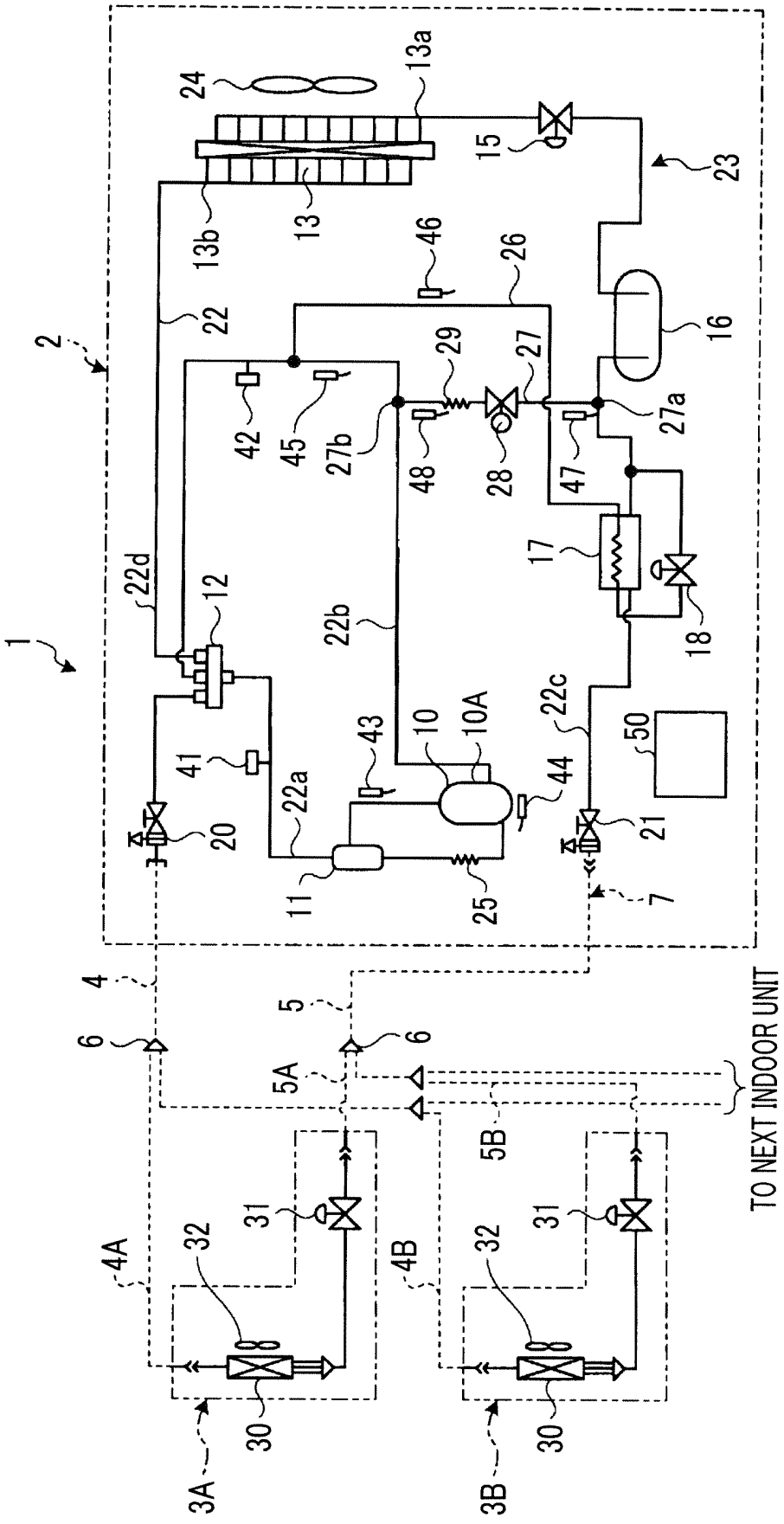
4. The refrigeration cycle device according to any one of claims 1 to 3, wherein in a case where it is determined that the liquid flooding is caused by leakage in the bypass valve, an opening and closing operation of the bypass valve is repeatedly executed.

5. The refrigeration cycle device according to any one of claims 1 to 4, wherein in a case where it is determined that the liquid flooding is not caused by leakage in the bypass valve, an operation of the compressor is stopped and an abnormality warning is issued.

6. A control method for determination of leaks in a bypass valve of a refrigeration cycle device in which a compressor, a condenser, an expansion valve, and an evaporator are connected to one another by piping and which has a bypass pipe having one end connected to a liquid pipe between the condenser and the evaporator and the other end connected to a suction pipe of the compressor, and bypassing the evaporator, and a bypass valve that controls a flow of a refrigerant in the bypass pipe, the method comprising:

a liquid flooding determination step of determining presence or absence of liquid flooding of the refrigerant to the compressor; and
a bypass valve leakage determination step of determining whether or not the liquid flooding is caused by leakage in the bypass valve, based on a first suction superheat degree of the refrigerant acquired further on the upstream side than the other end of the bypass pipe in the suction pipe.

FIG. 1


1
2
3A
3B
4
4A
4B
5
5A
5B
6
7
10
10A
11
12
13
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13b
15
16
17
18
20
21
22
22a
22b
22c
22d
23
24
25
26
27
27a
27b
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29
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31
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41
42
43
44
45
46
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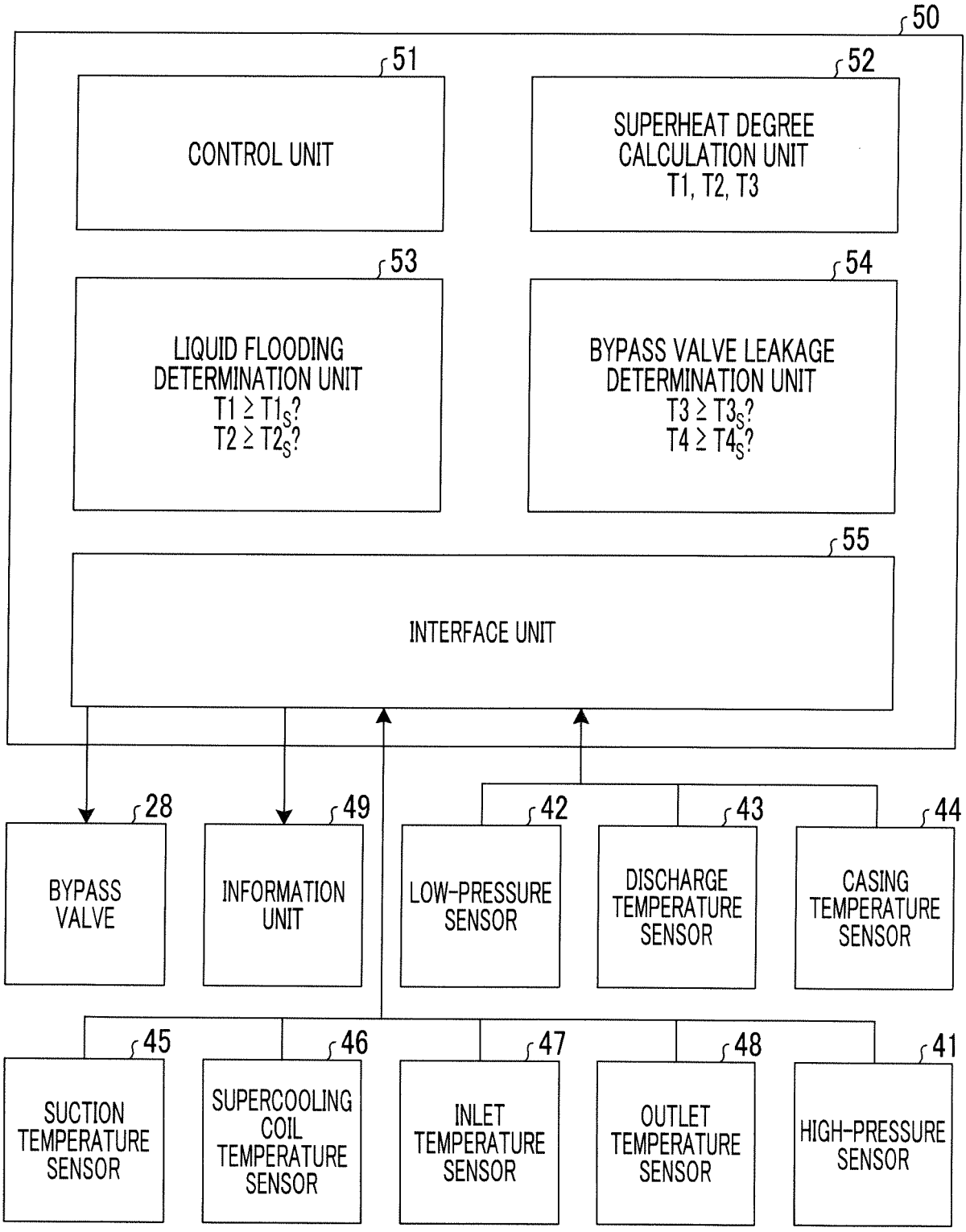
48
50
TO NEXT INDOOR UNIT

FIG. 2


50
51
CONTROL UNIT
52
SUPERHEAT DEGREE CALCULATION UNIT
T1, T2, T3
53
LIQUID FLOODING DETERMINATION UNIT
T1 ≥ T1S?
T2 ≥ T2S?
54
BYPASS VALVE LEAKAGE DETERMINATION UNIT
T3 ≥ T3S?
T4 ≥ T4S?
55
INTERFACE UNIT
28
BYPASS VALVE
49
INFORMATION UNIT
42
LOW-PRESSURE SENSOR
43
DISCHARGE TEMPERATURE SENSOR
44
CASING TEMPERATURE SENSOR
45
SUCTION TEMPERATURE SENSOR
46
SUPERCOOLING COIL TEMPERATURE SENSOR
47
INLET TEMPERATURE SENSOR
48
OUTLET TEMPERATURE SENSOR
41
HIGH-PRESSURE SENSOR

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/086936

A. CLASSIFICATION OF SUBJECT MATTER
F25B49/02(2006.01)i, *F25B1/00*(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)
F25B49/02, F25B1/00

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	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

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.
A	JP 2009-222272 A (Mitsubishi Electric Corp.), 01 October 2009 (01.10.2009), entire text; all drawings (Family: none)	1-6
A	JP 7-19642 A (Toshiba Corp.), 20 January 1995 (20.01.1995), entire text; all drawings (Family: none)	1-6
A	JP 4-324066 A (Daikin Industries, Ltd.), 13 November 1992 (13.11.1992), entire text; all drawings (Family: none)	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2017 (25.01.17)	14 February 2017 (14.02.17)

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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