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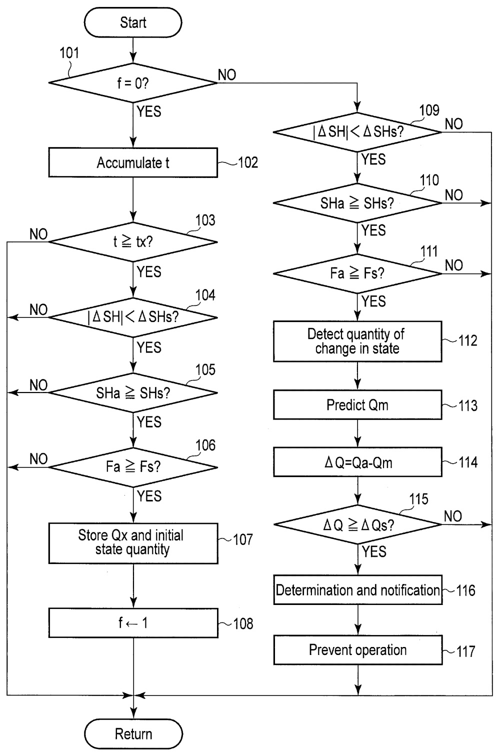
(71) Applicant: **Toshiba Carrier Corporation**
Kawasaki-shi, Kanagawa 212-8585 (JP)

(72) Inventors:
- **MIURA, Ken**
  Fuji-shi
  Shizuoka 416-8521 (JP)
- **HATADA, Takafumi**
  Fuji-shi
  Shizuoka 416-8521 (JP)
- **OKADA, Kaku**
  Fuji-shi
  Shizuoka 416-8521 (JP)

(74) Representative: **Plöger, Jan Manfred**
Gramm, Lins & Partner
Patent- und Rechtsanwälte PartGmbB
Theodor-Heuss-Strasse 1
38122 Braunschweig (DE)

(54) FREEZE CYCLING DEVICE

(57) A leakage detect section predicts a degree of opening of the expansion valve in a case where the refrigerant is not leaked from the refrigeration cycle based on a quantity of change in state of the refrigeration cycle. Then, the leakage detect section detects leakage of the refrigerant in the refrigeration cycle by comparing the predicted degree of opening with an actual degree of opening.



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Description

Technical Field

[0001] Embodiments described herein relate generally to a refrigeration cycle apparatus for preventing refrigerant leakage.

Background Art

[0002] In a refrigeration cycle in which a refrigerant discharged from a compressor is returned to the compressor through a condenser, a pressure reducing unit and an evaporator, the refrigerant is often leaked from, for example, a connection between pipes through which the refrigerant flows (for example, JP 2008-164265 A). It is required that the refrigerant leakage be reliably detected.

Disclosure of Invention

[0003] A refrigeration cycle apparatus of the present embodiment aims to detect refrigerant leakage with high reliability and accuracy.

[0004] The refrigeration cycle apparatus of the present embodiment comprising a refrigeration cycle, an opening control section and a leakage detect section. The leakage detect section predicts a degree of opening of the expansion valve in a case where the refrigerant is not leaked from the refrigeration cycle based on a quantity of change in state of the refrigeration cycle. The leakage detect section detects leakage of the refrigerant in the refrigeration cycle by comparing the predicted degree of opening with an actual degree of opening.

Brief Description of Drawings

[0005]

FIG. 1 is a block diagram showing a structure of an embodiment.
FIG. 2 is a flowchart showing control by a controller of the embodiment.
FIG. 3 is a cause and effect diagram showing various factors that determine the degree of opening of an expansion valve of the embodiment.
FIG. 4 is a graph showing the discrepancy amount between a predicted degree of opening of the expansion valve and an actual degree of opening of the expansion valve by using an amount of refrigerant leakage as a parameter.
FIG. 5 is a flowchart showing a modified example of the control by the controller of the embodiment.

Best Mode for Carrying Out the Invention

[0006] An embodiment will be described hereinafter with reference to the accompanying drawings. In the embodiment, a refrigeration cycle apparatus installed in an air-conditioning apparatus is described as an example.

[0007] As shown in FIG. 1, an outdoor heat exchanger 3 is connected to a discharge port of a compressor 1 through a four-way valve 2 and a packed valve 5 is connected to the outdoor heat exchanger 3 through an electrically-actuated expansion valve 4 by piping. An indoor heat exchanger 6 is connected to the packed valve 5 and a packed valve 7 is connected to the indoor heat exchanger 6 by piping. A suction port of the compressor 1 is connected to the packed valve 7 through the four-way valve 2 and an accumulator 8 by piping. A heat pump refrigeration cycle is configured by these piping connections.

[0008] The electrically-actuated expansion valve 4 is a pulse motor valve (PMV) whose degree of opening continuously varies according to the number of input drive pulses. An outdoor fan 11 is provided near the outdoor heat exchanger 3 and an indoor fan 12 is provided near the indoor heat exchanger 6.

[0009] The compressor 1 sucks a refrigerant from the suction port, compresses the refrigerant and discharges the refrigerant from the discharge port. In the case of cooling, as shown by arrows, the refrigerant discharged from the compressor 1 is sucked into the compressor 1 through the four-way valve 2, the outdoor heat exchanger 3, the electrically-actuated expansion valve 4, the packed valve 5, the indoor heat exchanger 6, the packed valve 7, the four-way valve 2 and the accumulator 8. By the flow of the refrigerant, the outdoor heat exchanger 3 functions as a condenser and the indoor heat exchanger 6 functions as an evaporator. In the case of heating, the flow passage of the four-way valve 2 is switched, and the refrigerant discharged from the compressor 1 is sucked into the compressor 1 through the four-way valve 2, the packed valve 7, the indoor heat exchanger 6, the packed valve 5, the electrically-actuated expansion valve 4, the outdoor heat exchanger 3, the four-way valve 2 and the accumulator 8. By the flow of the refrigerant, the indoor heat exchanger 6 functions as a condenser and the outdoor heat exchanger 3 functions as an evaporator.

[0010] A temperature sensor 21 is attached to the outdoor heat exchanger 3. A temperature sensor 22 is attached to a side of the indoor heat exchanger 6 from which the refrigerant flows into the indoor heat exchanger 6 in the case of cooling. A temperature sensor 23 is attached to piping between the four-way valve and the accumulator 8.

[0011] An outdoor unit A comprises the compressor 1, the four-way valve 2, the outdoor heat exchanger 3, the electrically-actuated expansion valve 4, the packed valve 5, the indoor heat exchanger 6, the packed valve 7, the accumulator 8, the outdoor fan 11, the temperature sensor 21 and the temperature sensor 23. An indoor unit B accommodates the indoor heat exchanger 6, the indoor fan 12 and the temperature sensor 22.

[0012] A controller 30 is connected to the outdoor unit A and the indoor unit B. A remote control operation unit 31, a manual reset switch 32 and an inverter 40 are connected to the controller 30.

[0013] The operation unit 31 is used for setting of operating conditions of the air-conditioning apparatus equipped with the refrigeration cycle apparatus. The reset switch 32 is an automatic-reset push-button switch and is provided on a control circuit board for mounting the controller 30. The inverter 40 converts an alternating-current voltage of a commercial alternating-current source 41 into a direct-current voltage by rectification, converts the direct-current voltage into an alternating-current voltage of a predetermined frequency F (Hz) and a level corresponding to the predetermined frequency F by switching, and outputs the alternating-current voltage. The output of the inverter 40 is supplied to a motor in the compressor 1 as driving power.

[0014] The controller 30 comprises a control section 51, a leakage detect section 52 and an updating section 53 as primary functions, and is equipped with a nonvolatile memory 54 for data storage.

[0015] The opening control section 51 controls the degree of opening of the electrically-actuated expansion valve 4 such that the degree of superheating SH of the refrigerant in an evaporator is constantly at a target value SHt (superheating constant value control). The evaporator is the indoor heat exchanger 6 in the case of cooling and is the outdoor heat exchanger 3 in the case of heating. The degree of superheating SH is the difference between a sensed temperature T2 of the temperature sensor 22 and a sensed temperature T3 of the temperature sensor 23 (= T3 - T2) in the case of cooling, and is the difference between a sensed temperature T1 of the temperature sensor 21 and the sensed temperature T3 of the temperature sensor 23 (= T3 - T1) in the case of heating.

[0016] The leakage detect section 52 predicts the degree of opening Qm of the electrically-actuated expansion valve 4 in the case where refrigerant leakage does not occur in the heat pump refrigeration cycle based on the quantity of change in state of the heat pump refrigeration cycle, and detects refrigerant leakage in the heat pump refrigeration cycle by comparing the predicted degree of opening Qm with an actual degree of opening Qa of the electrically-actuated expansion valve 4.

[0017] More specifically, the leakage detect section 52 stores the degree of opening Qx of the electrically-actuated expansion valve 4 at the beginning of operation of the heat pump refrigeration cycle in the memory 54, and a state quantity of the heat pump refrigeration cycle at the beginning of operation in the memory 54 as an initial state quantity (also referred to as an initial operation state quantity). The leakage detect section 52 detects the difference between the stored initial state quantity and a state quantity at the current stage of operation of the heat pump refrigeration cycle (also referred to as a current state quantity) as the quantity of change in state. Based on the detected quantity of change in state, the leakage detect section 52 predicts (estimates) the degree of opening Qm of the electrically-actuated expansion valve 4 in the case where refrigerant leakage does not occur in the heat pump refrigeration cycle. Then, the leakage detect section 52 detects refrigerant leakage in the heat pump refrigeration cycle based on the difference between the predicted degree of opening Qm and an actual degree of opening Qa of the electrically-actuated expansion valve 4.

[0018] The predicted degree of opening Qm is hereinafter referred to as the predicted degree of opening (or estimated degree of opening) Qm. The predicted degree of opening Qm is the degree of opening that the electrically-actuated expansion valve 4 should attain to at the current stage of operation of the heat pump refrigeration cycle on the premise that refrigerant leakage does not occur in the heat pump refrigeration cycle.

[0019] The initial state quantity is at least one of an operating frequency Fx, a condensation temperature Tcx, an evaporation temperature Tex and the degree of superheating SHx at the moment when set time tx (for example, 10 to 50 hours) has passed since the reset switch 32 was operated.

[0020] The operating frequency Fx is an operating frequency of the compressor 1 (output frequency of the inverter 40). The condensation temperature Tcx is the sensed temperature T1 of the temperature sensor 21 attached to the outdoor heat exchanger 3 in the case of cooling, and is the sensed temperature T2 of the temperature sensor 22 attached to the indoor heat exchanger 6 in the case of heating. The evaporation temperature Tex is the sensed temperature T2 of the temperature sensor 22 attached to the indoor heat exchanger 6 in the case of cooling, and is the sensed temperature T1 of the temperature sensor 21 attached to the outdoor heat exchanger 3 in the case of heating. The degree of superheating SHx is the difference between the sensed temperature T2 of the temperature sensor 22 and the sensed temperature T3 of the temperature sensor 23 (= T3 - T2) in the case of cooling, and is the difference between the sensed temperature T1 of the temperature sensor 21 and the sensed temperature T3 of the temperature sensor 23 (= T3 - T1) in the case of heating.

[0021] The state quantity at the current stage of operation of the heat pump refrigeration cycle is at least one of an operating frequency Fa, a condensation temperature Tca, an evaporation temperature Tea and the degree of superheating SHa at the current stage of operation of the heat pump refrigeration cycle.

[0022] For example, when the leakage detect section 52 stores the operating frequency Fx, the condensation temperature Tcx, the evaporation temperature Tex and the degree of superheating SHx as the initial state quantity, the leakage detect section 52 extracts the operating frequency Fa, the condensation temperature Tca, the evaporation temperature Tea and the degree of superheating SHa as the current state quantity. For example, when the leakage detect section 52 stores the operating frequency Fx, the condensation temperature Tcx and the evaporation temperature Tex as the initial state quantity, the leakage detect section 52 extracts the operating frequency Fa, the condensation temperature Tca and the evaporation temperature Tea as the current state quantity. For example, when the leakage detect section 52 stores the operating frequency Fx and the condensation temperature Tcx as the initial state quantity, the leakage detect section 52 extracts the operating frequency Fa and the condensation temperature Tca as the current state quantity. For example, when the leakage detect section 52 stores the operating frequency Fx as the initial state quantity, the leakage detect section 52 extracts the operating frequency Fa as the current state quantity.

[0023] The updating section 53 updates the initial state quantity in the memory 54 in response to tuning on of the reset switch 32.

[0024] Next, control executed by the controller 30 is described with reference to a flowchart of FIG. 2.

[0025] The controller 30 determines whether an initial state flag f is "0" (step 101). The initial state flag f indicates whether the degree of opening Qx and the initial state quantity have already been stored. The controller 30 resets the initial state flag f to "0" when the reset switch 32 is turned on by a user or worker.

[0026] When the initial state flag f is "0" (YES in step 101), the controller 30 determines that the degree of opening Qx and the initial state quantity are not yet stored, accumulates operating time t (step 102) and determines whether the accumulated operating time t is greater than or equal to the set time tx ($t \geq tx$) (step 103). The accumulated operating time t is successively stored in the memory 54 of the controller 30 for update. When the reset switch 32 is turned on, the controller 30 zeros the accumulated operating time t. The set time tx is a value from 10 to 50 hours, which is the beginning of operation. A suitable value is selected as the set time tx depending on an environment in which the refrigeration cycle apparatus is installed, etc.

[0027] When the accumulated operating time t is less than the set time tx (NO in step 103), the controller 30 returns to the flag determination in step 101.

[0028] When the accumulated operating time t reaches the set time tx (YES in step 103), the controller 30 determines whether the heat pump refrigeration cycle is in a stable operating state (steps 104, 105 and 106).

[0029] That is, in step 104, the controller 30 determines whether an absolute value ($|\Delta SH|$) of the difference ΔSH between the degree of superheating SHa at the current stage of operation of the heat pump refrigeration cycle and the target value SHt is less than a set value ΔSHs ($|\Delta SH| < \Delta SHs$). The set value ΔSHs is, for example, 2 to 3 K. In step 105, the controller 30 determines whether the degree of superheating SHa at the current stage of operation of the heat pump refrigeration cycle is greater than or equal to a set value SHs ($SHa \geq SHs$). The set value SHs is, for example, 1 to 2 K. When the degree of superheating SHa is greater than or equal to the set value SHs, the degree of superheating SHa is a positive value. In step 106, the controller 30 determines whether the operating frequency Fa of the compressor 1 at the current stage of operation of the heat pump refrigeration cycle is greater than or equal to a set value Fs ($Fa \geq Fs$). The set value Fs is, for example, 30 Hz.

[0030] When at least one of the determination results of steps 104, 105 and 106 is no (NO in step 104, NO in step 105 or NO in step 106), the controller 30 returns to the flag determination in step 101.

[0031] When all the determination results of steps 104, 105 and 106 are yes (YES in step 104, YES in step 105 and YES in step 106), the controller 30 determines that the heat pump refrigeration cycle is brought into the stable operating state, stores the degree of opening Qx of the electrically-actuated expansion valve 4 at that time in memory 54 for update, and stores the operating frequency Fx, the condensation temperature Tcx, the evaporation temperature Tex and the degree of superheating SHx as the initial state quantity in the memory 54 for update (step 107).

[0032] In response to the storage of the degree of opening Qx and the initial state quantity, the controller 30 sets the initial state flag f to "1" (step 108) and returns to the flag determination in step 101.

[0033] When the initial state flag f is "1" (NO in step 101), the controller 30 determines whether the heat pump refrigeration cycle is in the stable operating state (steps 109, 110 and 111).

[0034] That is, in step 109, the controller 30 determines whether an absolute value ($|\Delta SH|$) of the difference ΔSH between the degree of superheating SHa at the current stage of operation of the heat pump refrigeration cycle and the target value SHt is less than a set value ΔSHs ($|\Delta SH| < \Delta SHs$). The set value ΔSHs is, for example, 2 to 3 K. In step 110, the controller 30 determines whether the degree of superheating SHa at the current stage of operation of the heat pump refrigeration cycle is greater than or equal to a set value SHs ($SHa \geq SHs$). The set value SHs is, for example, 1 to 2 K. When the degree of superheating SHa is greater than or equal to the set value SHs, the degree of superheating

SH is a positive value. In step 111, the controller 30 determines whether the operating frequency Fa of the compressor 1 at the current stage of operation of the heat pump refrigeration cycle is greater than or equal to a set value Fs ($Fa \geq Fs$). The set value Fs is, for example, 30 Hz.

[0035] When at least one of the determination results of steps 109, 110 and 111 is no (NO in step 109, NO in step 110 or NO in step 111), the controller 30 returns to the flag determination in step 101.

[0036] When all the determination results of steps 109, 110 and 111 are yes (YES in step 109, YES in step 110 and YES in step 111), the controller 30 determines that the heat pump refrigeration cycle is brought into the stable operating state, and detects the difference between the state quantity at the current stage of operation of the heat pump refrigeration cycle and the initial state quantity in the memory 54 as the quantity of change in state (step 112).

[0037] The state quantity at the current stage of operation of the heat pump refrigeration cycle is the operating frequency Fa, the condensation temperature Tca, the evaporation temperature Tea and the degree of superheating SHa. The quantity of change in state is the difference ΔF between the operating frequency Fx and the operating frequency Fa, the difference ΔTc between the condensation temperature Tcx and the condensation temperature Tca, the difference ΔTe between the evaporation temperature Tex and the evaporation temperature Tea, and the difference $\Delta SHxa$ between the degree of superheating SHx and the degree of superheating SHa.

[0038] Next, the controller 30 predicts the degree of opening Qm of the electrically-actuated expansion valve 4 in the case where the heat pump refrigeration cycle stably operates without refrigerant leakage, based on the detected quantity of change in state (step 113). The prediction is hereinafter described.

[0039] As shown in a cause and effect diagram of FIG. 3, factors that determine the degree of opening Q of the electrically-actuated expansion valve 4 include "degree of dryness", "refrigerant circulating amount", "evaporation temperature Te" and "condensation temperature Tc". The degree of dryness is a weight ratio between a saturated liquid and vapor (dry saturated vapor) in the case where the refrigerant is wet saturated vapor.

[0040] From these factors, the following theoretical formula expressing the degree of opening Q of the electrically-actuated expansion valve 4 can be obtained:

$$Q = L \cdot (\rho / \Delta P) \wedge 0.5$$

where L is the refrigerant circulating amount, ρ is the refrigerant density on the refrigerant inlet side of the electrically-actuated expansion valve 4, and ΔP is the difference between pressure P1 of the refrigerant on the refrigerant inlet side of the electrically-actuated expansion valve 4 and pressure P2 of the refrigerant on the refrigerant outlet side of the electrically-actuated expansion valve 4 (= P1 - P2). ΔP is hereinafter referred to as the refrigerant pressure difference.

[0041] The factors except the refrigerant density p, i.e., the refrigerant circulating amount L and the refrigerant pressure difference ΔP can be obtained by an operation using the operating frequency F, the condensation temperature Tc, the evaporation temperature Te and the degree of superheating SH. The refrigerant density ρ can be obtained by correcting the degree of opening Q by using the operating frequency F, the condensation temperature Tc, the evaporation temperature Te and the degree of superheating SH. The amount of change in the refrigerant density ρ is also the amount of change in the refrigerant in the heat pump refrigeration cycle. That is, whether refrigerant leakage occurs can be determined based on the amount of change in the refrigerant density p.

[0042] Even if the refrigerant amount is reduced by refrigerant leakage, the parameters for the above operation, i.e., the operating frequency F, the condensation temperature Tc, the evaporation temperature Te and the degree of superheating SH, are not significantly affected by the reduction in the refrigerant amount.

[0043] Therefore, the degree of opening Qm of the electrically-actuated expansion valve 4 in the case where refrigerant leakage does not occur in the heat pump refrigeration cycle can be predicted (estimated) by the following operational expression of correcting the degree of opening Qx stored in the memory 54 at the beginning of operation by the quantity of change in state from the beginning of operation to the current stage of operation, i.e., ΔF, ΔTc, ΔTe and $\Delta SHxa$. The predicted degree of opening Qm is a proper degree of opening that the electrically-actuated expansion valve 4 should attain to at the current stage of operation on the premise that refrigerant leakage does not occur in the heat pump refrigeration cycle.

$$Qm = a \cdot \Delta F + b \cdot \Delta Tc + c \cdot \Delta Te + d \cdot \Delta SHxa + Qx$$

where a, b, c and d are constants preliminarily obtained by experiment. "$a \cdot \Delta F + b \cdot \Delta Tc + c \cdot \Delta Te + d \cdot \Delta SHxa$" corresponds to the amount of change in the degree of opening of the electrically-actuated expansion valve 4 from the storage of the initial degree of opening Qx to the current stage of operation.

[0044] If refrigerant leakage occurs and the amount of the refrigerant in the heat pump refrigeration cycle is reduced (i.e., the refrigerant density ρ decreases), the electrically-actuated expansion valve 4 is adjusted to the degree of opening greater than the predicted degree of opening Qm by the superheating constant value control by the controller 30.

[0045] The controller 30 successively recognizes the actual degree of opening Qa of the electrically-actuated expansion valve 4. The controller 30 obtains the discrepancy amount ΔQ between the actual degree of opening Qa and the predicted degree of opening Qm (= Qa - Qm) (step 114). Then, the controller 30 determines whether the obtained discrepancy amount ΔQ is greater than or equal to a threshold value ΔQs (step 115). The threshold value ΔQs is the degree of opening corresponding to, for example, 100 to 200 drive pulses. A suitable value is selected as the threshold value ΔQs depending on the capacity of devices constituting the heat pump refrigeration cycle and the length of piping.

[0046] When the discrepancy amount ΔQ is greater than or equal to the threshold value ΔQs (YES in step 115), the controller 30 determines that refrigerant leakage occurs in the heat pump refrigeration cycle, and notifies the user of that effect by, for example, display of characters or an icon image on the operation unit 31 (step 116). The user can understand that the refrigerant leakage occurs by the notification and request maintenance or inspection.

[0047] With the notification, the controller 30 deactivates the compressor 1 and prevents the compressor 1 from operating (step 117). Since the compressor 1 is prevented from operating, the compressor 1 does not operate while the refrigerant leaks, and the adverse effect on the refrigeration cycle device can be avoided.

[0048] The discrepancy amount ΔQ is obtained by experimenting using the amount of refrigerant leakage as a parameter and is plotted in FIG. 4. The solid line indicates the normal refrigerant amount, and broken lines indicate the discrepancy amount

broken lines indicate the discrepancy amount ΔQ [%] (= (Qa - Qm)/Qa_max). Qa_max is the maximum degree of

Qa_max is the maximum degree of opening of the electrically-actuated expansion valve 4.

[0049] When Qa = Qm, the discrepancy amount ΔQ is 0 (%). On the assumption that the degree of opening of the fully-open electrically-actuated expansion valve 4 corresponds to 500 pulses, the discrepancy amount ΔQ = 10 (%) corresponds to 50 pulses.

[0050] As described above, whether refrigerant leakage occurs in the heat pump refrigeration cycle can be reliably determined regardless of the length of piping in the heat pump refrigeration cycle and the difference in specification between the air-conditioning apparatuses equipped with the refrigeration cycle apparatus, by predicting the degree of opening Qm of the electrically-actuated expansion valve 4 in the case where refrigerant leakage does not occur based on the quantity of change in state of the heat pump refrigeration cycle, and detecting refrigerant leakage by comparing the predicted degree of opening Qm with the actual degree of opening Qa.

[0051] Since the degrees of change ΔF, ΔTc, ΔTe and ΔSHxa in the operating frequency F, the condensation temperature Tc, the evaporation temperature Te and the degree of superheating SH, respectively, which are not significantly affected by refrigerant leakage, are used as the quantity of change in state of the heat pump refrigeration cycle, the degree of opening Qm can be predicted with high accuracy. As a result, the threshold value ΔQs for leakage detection can be set to a low value. Since the threshold value ΔQs for leakage detection can be set to a low value, refrigerant leakage can be accurately detected even if the amount of refrigerant leakage is small.

[0052] When refrigerant recovery operation for recovering the refrigerant in the heat pump refrigeration cycle is executed and the refrigeration cycle apparatus is relocated, the user or worker turns on the reset switch 32 after the relocation. When the reset switch 32 is turned on, the controller 30 stores the degree of opening Qx and an initial state quantity of new operation in the memory 54 for update. By the update, whether refrigerant leakage occurs can be reliably detected after the relocation.

[0053] Since the degree of opening Qx and the initial state quantity are stored and refrigerant leakage is detected on the condition that the heat pump refrigeration cycle is in the stable operating state, the accuracy of leakage detection is improved.

[0054] As factors that determine whether the heat pump refrigeration cycle is in the stable operating state, a plurality of conditions, i.e., a condition that an absolute value ΔSH of the difference between the degree of superheating SHa and the target value SHt is less than the value ΔSHs, and a condition that the degree of superheating SHa is greater than or equal to the set value SHs (degree of superheating SH is a positive value), are used. Therefore, refrigerant leakage can be detected without absorption of liquid refrigerant into the compressor 1 and operating delay of the electrically-actuated expansion valve 4. That is, the detection accuracy is improved.

[0055] The liquid refrigerant is often accumulated in the outdoor heat exchanger 3 when the operating frequency F is low. However, refrigerant leakage can be detected without accumulation of the liquid refrigerant in the outdoor heat exchanger 3 because a condition that the operating frequency Fa is greater than or equal to the set value Fs is further added as a factor that determines whether the heat pump refrigeration cycle is in the stable operating state. In this point, too, the detection accuracy is improved.

[Modified Example]

[0056] In the above-described embodiment, the condition "$|\Delta SH| < \Delta SHs$" in steps 104 and 109 is used as a factor that determines whether the heat pump refrigeration cycle is in the stable operating state, but a condition of steps 104a and 109a shown in FIG. 5 may be used instead.

[0057] That is, when the amount of change ΔQa per unit time in the degree of opening Qa of the electrically-actuated expansion valve 4 is maintained at a value less than a set value ΔQas for a certain period ty at the beginning of operation (f = 0) (YES in step 104a), the controller 30 determines this condition as one of factors of the stable operating state. When the amount of change ΔQa per unit time in the degree of opening Qa of the electrically-actuated expansion valve 4 is maintained at a value less than a set value ΔQas for the certain period ty after the degree of opening Qx and the initial state quantity are stored (f = 1) (YES in step 109a), the controller 30 determines this condition as one of factors of the stable operating state.

[0058] The set value ΔQas is the degree of opening corresponding to, for example, 3 to 5 drive pulses. A suitable value is determined as the set value ΔQas depending on the capacity of refrigeration cycle device and the length of piping. The certain period ty is, for example, 3 to 5 minutes. A suitable value is determined as the certain period ty depending on the capacity of refrigeration cycle device and the length of piping.

[0059] ΔF, ΔTc, ΔTe and ΔSHxa are used as the quantity of change in state in the above-described embodiment, but only ΔF and ΔTc may be used as the quantity of change in state. At least one of ΔF, ΔTc, ΔTe and ΔSHxa may be used as the quantity of change in state.

[0060] In the above-described embodiment, the manual reset switch 32 is provided as a means for updating the stored degree of opening Qx and the stored initial state quantity, but this means may be provided in the operation unit 31. In addition to updating the degree of opening Qx and the initial state quantity in accordance with the operation of the reset switch 32, the degree of opening Qx and the initial state quantity may be automatically updated. That is, after the controller 30 executes the refrigerant recovery operation for relocation of the refrigeration cycle apparatus, the controller 30 automatically updates the stored degree of opening Qx and the stored initial state quantity.

[0061] In the above-described embodiment, the refrigeration cycle apparatus is installed in the air-conditioning apparatus, but the embodiment can also be applied to a refrigeration cycle apparatus installed in other apparatuses such as a boiler.

[0062] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Industrial Applicability

[0063] The refrigeration cycle apparatus of the present embodiment can be applied to an air-conditioning apparatus.

Claims

1. A refrigeration cycle apparatus **characterized by** comprising:

   a refrigeration cycle including a compressor configured to sucked, compress and discharge a refrigerant, the refrigeration cycle allowing the refrigerant discharged from the compressor to be returned to the compressor through a condenser, an expansion valve and an evaporator;
   an opening control section configured to control a degree of opening of the expansion valve such that a degree of superheating of the evaporator is at a target value; and
   a leakage detect section configured to predict, based on a quantity of change in state of the refrigeration cycle, a degree of opening of the expansion valve in a case where the refrigerant is not leaked from the refrigeration cycle, and to detect leakage of the refrigerant in the refrigeration cycle by comparing the predicted degree of opening with an actual degree of opening.

2. The refrigeration cycle apparatus of Claim 1, **characterized in that**
   the leakage detect section detects a difference between a state quantity at beginning of operation of the refrigeration cycle and a state quantity at a current stage of operation of the refrigeration cycle as the quantity of change in state, and the leakage detect section predicts the degree of opening of the expansion valve in the case where the refrigerant

is not leaked from the refrigeration cycle by correcting a degree of opening of the expansion valve at the beginning of operation of the refrigeration cycle by the detected quantity of change in state.

3. The refrigeration cycle apparatus of Claim 1, **characterized in that**
the leakage detect section stores a degree of opening of the expansion valve at beginning of operation of the refrigeration cycle, and stores a state quantity at the beginning of operation of the refrigeration cycle as an initial state quantity,
the leakage detect section detects a difference between the stored initial state quantity and a state quantity at a current stage of operation of the refrigeration cycle as the quantity of change in state, and
the leakage detect section predicts the degree of opening of the expansion valve in the case where the refrigerant is not leaked from the refrigeration cycle by correcting the stored degree of opening by the detected quantity of change in state.

4. The refrigeration cycle apparatus of Claim 1, **characterized in that**
the leakage detect section accumulates operating time of the refrigeration cycle,
the leakage detect section stores a degree of opening of the expansion valve at timing when the accumulated operating time reaches set time, and stores a state quantity of the refrigeration cycle at the timing as an initial state quantity,
the leakage detect section detects a difference between the stored initial state quantity and a state quantity at a current stage of operation of the refrigeration cycle as the quantity of change in state, and
the leakage detect section predicts the degree of opening of the expansion valve in the case where the refrigerant is not leaked from the refrigeration cycle by correcting the stored degree of opening by the detected quantity of change in state.

5. The refrigeration cycle apparatus of Claim 1, **characterized in that**
the leakage detect section accumulates operating time of the refrigeration cycle,
after the accumulated operating time reaches set time, the leakage detect section determines whether the refrigeration cycle is in a stable operating state,
when the leakage detect section determines that the refrigeration cycle is in the stable operating state, the leakage detect section stores a degree of opening of the expansion valve at this time, and stores a state quantity of the refrigeration cycle at this time as an initial state quantity,
the leakage detect section detects a difference between the stored initial state quantity and a state quantity at a current stage of operation of the refrigeration cycle as the quantity of change in state, and
the leakage detect section predicts the degree of opening of the expansion valve in the case where the refrigerant is not leaked from the refrigeration cycle by correcting the stored degree of opening by the detected quantity of change in state.

6. The refrigeration cycle apparatus of Claim 5, **characterized in that**
the leakage detect section determines that the refrigeration cycle is in the stable operating state when a condition that an absolute value ($|\Delta SH|$) of a difference ΔSH between a degree of superheating SHa at the current stage of operation of the refrigeration cycle and a target value SHt is less than a set value ΔSHs ($|\Delta SH| < \Delta SHs$), a condition that the degree of superheating SHa at the current stage of operation of the refrigeration cycle is greater than or equal to a set value SHs ($SHa \geq SHs$), and a condition that an operating frequency Fa of the compressor at the current stage of operation of the refrigeration cycle is greater than or equal to a set value Fs ($Fa \geq Fs$) are satisfied.

7. The refrigeration cycle apparatus of Claim 5, **characterized in that**
the leakage detect section determines that the refrigeration cycle is in the stable operating state when a condition that a amount of change ΔQa per unit time in the actual degree of opening Qa of the electrically-actuated expansion valve is maintained at a value less than a set value ΔQas for a certain period ty, a condition that a degree of superheating SHa at the current stage of operation of the refrigeration cycle is greater than or equal to a set value SHs ($SHa \geq SHs$), and a condition that an operating frequency Fa of the compressor at the current stage of operation of the refrigeration cycle is greater than or equal to a set value Fs ($Fa \geq Fs$) are satisfied.

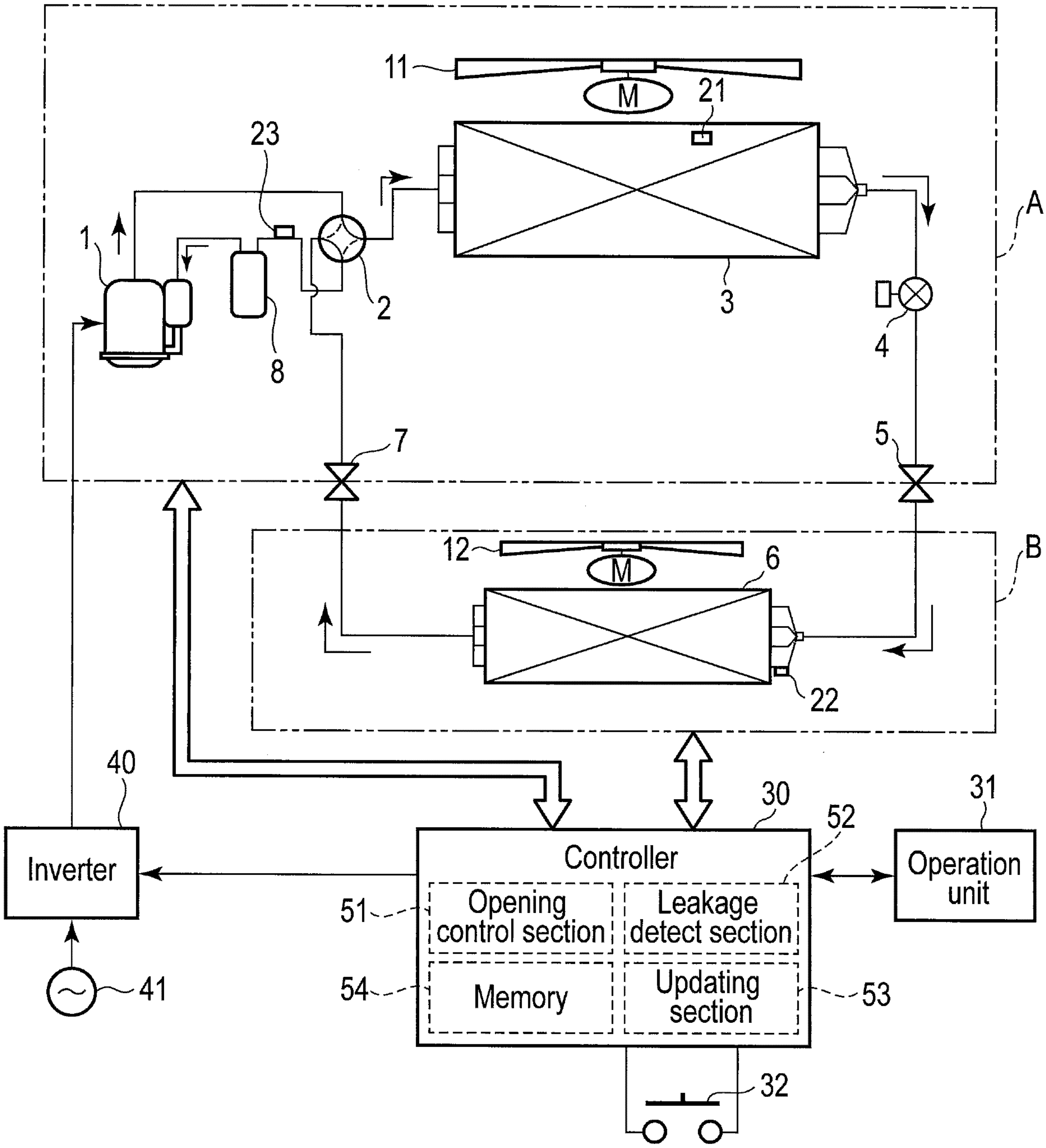
8. The refrigeration cycle apparatus of any one of Claims 3 to 7, **characterized in that**
the initial state quantity is at least one of an operating frequency Fx of the compressor, and a condensation temperature Tcx, an evaporation temperature Tex and a degree of superheating SHx of the refrigeration cycle,
the state quantity at the current stage of operation of the refrigeration cycle is at least one of an operating frequency Fa of the compressor, and a condenser temperature Tca, an evaporator temperature Tea and a degree of super-

heating SHa at the current stage of operation of the refrigeration cycle,
the quantity of change in state is at least one of a difference ΔF between the operating frequency Fx and the operating frequency Fa, a difference ΔTc between the condensation temperature Tcx and the condensation temperature Tca, a difference ΔTe between the evaporation temperature Tex and the evaporation temperature Te, and a difference $\Delta SHxa$ between the degree of superheating SHx and the degree of superheating SHa.

9. The refrigeration cycle apparatus of any one of Claims 3 to 5, **characterized by** further comprising
an updating section configured to update the stored degree of opening and the stored initial state quantity.

10. The refrigeration cycle apparatus of Claim 9, **characterized by** further comprising a manual reset switch, and **characterized in that**
the updating section updates the stored degree of opening and the stored initial state quantity in accordance with operation of the reset switch.

11. The refrigeration cycle apparatus of Claim 9, **characterized in that**
after refrigerant recovery operation for recovering the refrigerant in the refrigeration cycle is executed, the updating section automatically updates the stored degree of opening and the stored initial state quantity.


11
21
23
1
2
3
8
4
A
7
5
12
6
B
22
40
30
52
31
Inverter
Controller
Operation unit
51
Opening control section
Leakage detect section
54
Memory
Updating section
53
41
32

F I G. 1

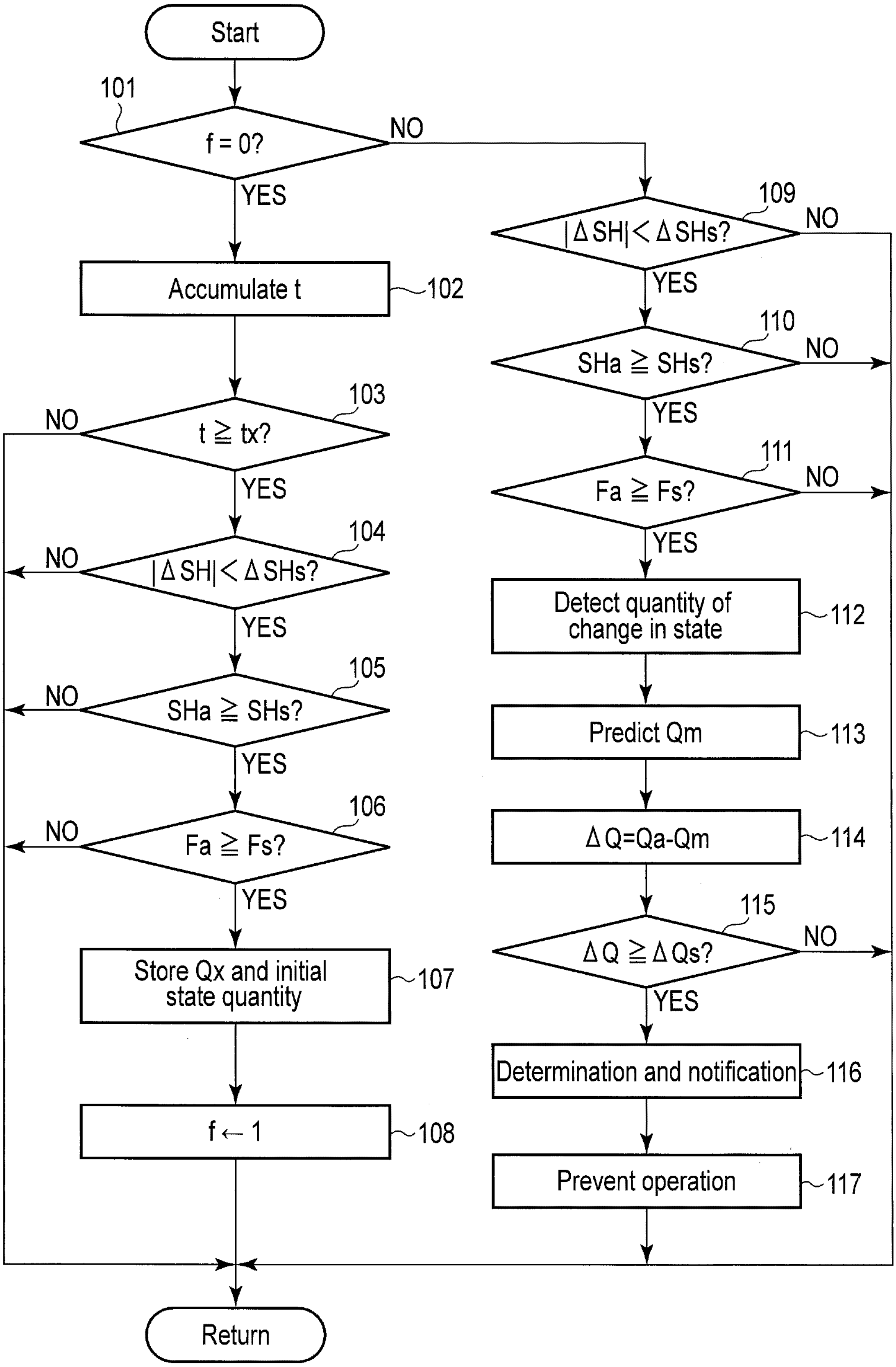
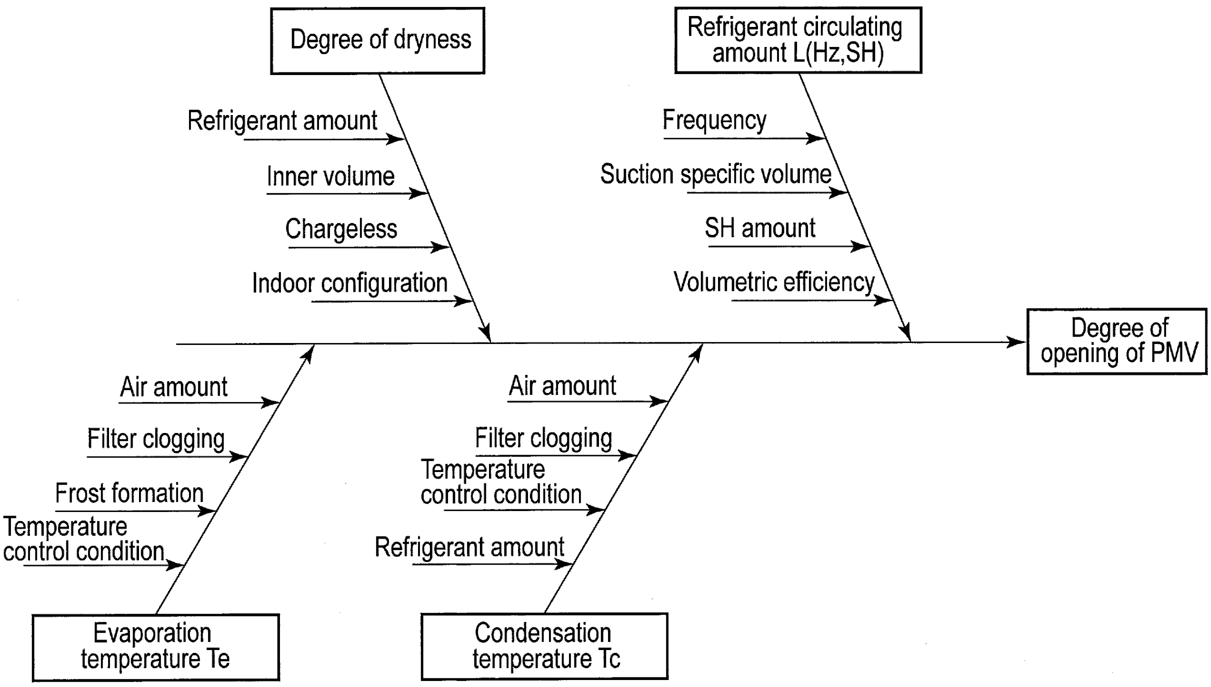
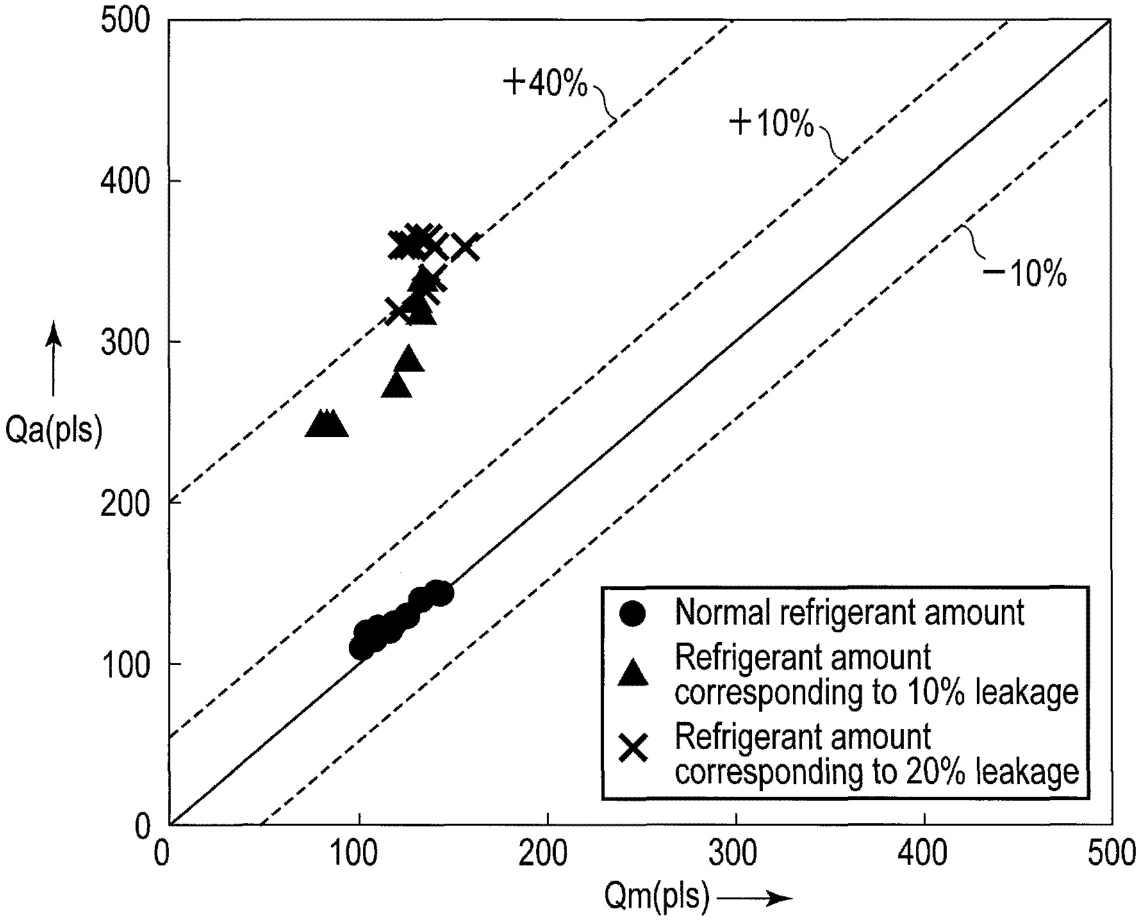

Start
101
f = 0?
NO
YES
Accumulate t
102
103
t ≧ tx?
NO
YES
104
|ΔSH|<ΔSHs?
NO
YES
105
SHa ≧ SHs?
NO
YES
106
Fa ≧ Fs?
NO
YES
Store Qx and initial state quantity
107
f ← 1
108
109
|ΔSH|<ΔSHs?
NO
YES
110
SHa ≧ SHs?
NO
YES
111
Fa ≧ Fs?
NO
YES
Detect quantity of change in state
112
Predict Qm
113
ΔQ=Qa-Qm
114
115
ΔQ ≧ ΔQs?
NO
YES
Determination and notification
116
Prevent operation
117
Return

FIG. 2



Degree of dryness
Refrigerant amount
Inner volume
Chargeless
Indoor configuration
Refrigerant circulating amount L(Hz,SH)
Frequency
Suction specific volume
SH amount
Volumetric efficiency
Degree of opening of PMV
Air amount
Filter clogging
Frost formation
Temperature control condition
Evaporation temperature Te
Air amount
Filter clogging
Temperature control condition
Refrigerant amount
Condensation temperature Tc

F I G. 3


500
400
300
200
100
0
Qa(pls)
0
100
200
300
400
500
Qm(pls)
+40%
+10%
−10%
Normal refrigerant amount
Refrigerant amount corresponding to 10% leakage
Refrigerant amount corresponding to 20% leakage

F I G. 4

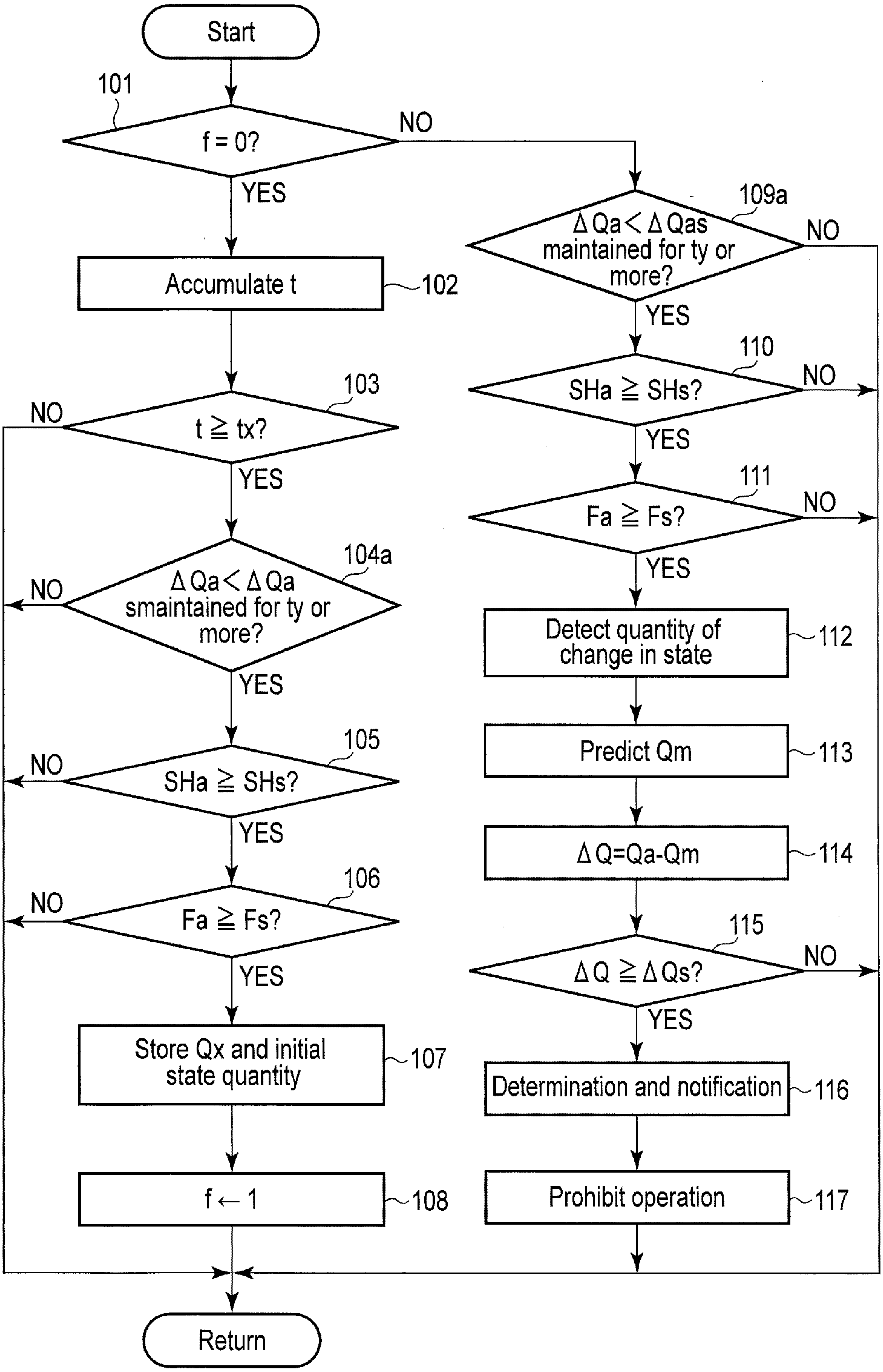

Start
101
f = 0?
NO
YES
Accumulate t
102
103
t ≧ tx?
NO
YES
104a
ΔQa<ΔQa smaintained for ty or more?
NO
YES
105
SHa ≧ SHs?
NO
YES
106
Fa ≧ Fs?
NO
YES
Store Qx and initial state quantity
107
f←1
108
109a
ΔQa<ΔQas maintained for ty or more?
NO
YES
110
SHa ≧ SHs?
NO
YES
111
Fa ≧ Fs?
NO
YES
Detect quantity of change in state
112
Predict Qm
113
ΔQ=Qa-Qm
114
115
ΔQ ≧ ΔQs?
NO
YES
Determination and notification
116
Prohibit operation
117
Return

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/074874

A. CLASSIFICATION OF SUBJECT MATTER
F25B49/02(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)
F25B49/02

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2009-222272 A (Mitsubishi Electric Corp.), 01 October 2009 (01.10.2009), entire text; all drawings (particularly, paragraphs [0011] to [0013], [0024]; fig. 1 to 3) (Family: none)	1-11
Y	JP 2012-202672 A (Mitsubishi Heavy Industries, Ltd.), 22 October 2012 (22.10.2012), entire text; all drawings (particularly, claim 1; paragraph [0040]; fig. 1 to 4) & US 2013/0180272 A1 & EP 2693136 A1 & WO 2012/132944 A & WO 2012/132944 A1 & KR 10-2013-0037730 A & CN 103443563 A	1-11

☒ 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
09 December, 2014 (09.12.14)	22 December, 2014 (22.12.14)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/074874

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 2011-220624 A (Mitsubishi Electric Corp.), 04 November 2011 (04.11.2011), entire text; all drawings (particularly, paragraphs [0080] to [0085]; fig. 10) (Family: none)	2-11
Y	JP 8-21675 A (Hitachi, Ltd.), 23 January 1996 (23.01.1996), entire text; all drawings (particularly, paragraphs [0016] to [0026]; fig. 2 to 6, 8) (Family: none)	6-7
Y	JP 2006-50524 A (Mitsubishi Electric Corp.), 16 February 2006 (16.02.2006), entire text; all drawings (particularly, paragraphs [0022], [0030], [0065]) (Family: none)	9-11
A	JP 2011-64357 A (Daikin Industries, Ltd.), 31 March 2011 (31.03.2011), entire text; all drawings (Family: none)	1-8
A	JP 2010-223542 A (Mitsubishi Electric Corp.), 07 October 2010 (07.10.2010), entire text; all drawings (particularly, paragraphs [0070] to [0167]; fig. 1 to 12) (Family: none)	1-8
A	JP 6-281266 A (Sanyo Electric Co., Ltd.), 07 October 1994 (07.10.1994), entire text; all drawings (particularly, paragraphs [0031] to [0041]; fig. 1 to 5) & US 5442926 A & CN 1098186 A	1-5
A	JP 2008-196829 A (Mitsubishi Electric Corp.), 28 August 2008 (28.08.2008), entire text; all drawings (particularly, paragraph [0037]; fig. 1 to 5) (Family: none)	1-5
A	JP 6-273013 A (Toshiba Corp.), 30 September 1994 (30.09.1994), entire text; all drawings (particularly, paragraphs [0012] to [0018]; fig. 1 to 9) (Family: none)	1-7
A	JP 2008-249234 A (Mitsubishi Electric Corp.), 16 October 2008 (16.10.2008), entire text; all drawings (Family: none)	1-7

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008164265 A **[0002]**