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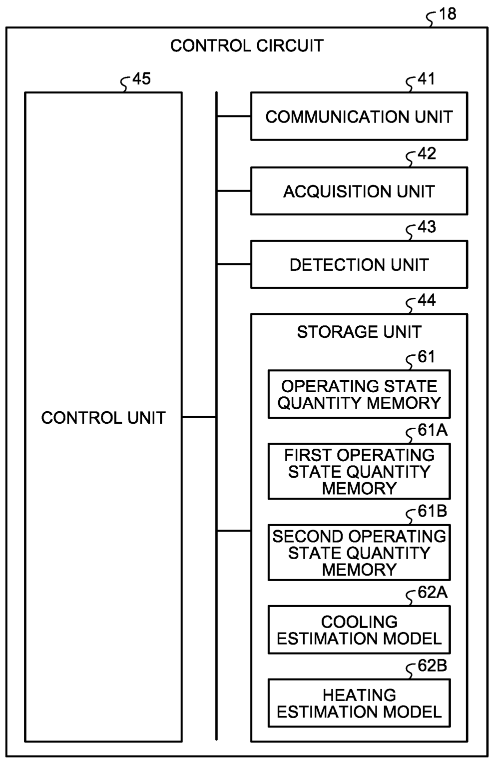
(54) AIR CONDITIONER

(57) An air conditioner includes a refrigerant circuit that is formed by connecting, by a refrigerant pipe, an indoor unit including an indoor heat exchanger to an outdoor unit including a compressor, an outdoor heat exchanger, and an expansion valve, where the refrigerant circuit is filled with a predetermined amount of a refrigerant. The air conditioner includes an acquisition unit that regularly acquires an operating state quantity at a time of air conditioning operation, a storage unit that stores therein the operating state quantity that is acquired by the acquisition unit, an estimation model that estimates a refrigerant remaining amount in the refrigerant circuit by using the operating state quantity, a detection unit that detects, from the storage unit, one of a first operating state quantity being an operating state quantity in a state in which the refrigerant circuit meets a first stability condition and a second operating state quantity being an operating state quantity in a state in which the refrigerant circuit meets a second stability condition that is different from the first stability condition, and a control unit that estimates the remaining refrigerant amount in the refrigerant circuit by using the estimation model and the detected operating state quantity. Even when the air conditioner is actually operating, it is possible to estimate the remaining refrigerant amount in the refrigerant circuit.

FIG.3



EP 4 235 046 A1

Description

Field

[0001] The present invention relates to an air conditioner.

Background

[0002] An air conditioner that determines a refrigerant amount by using an operating state quantity that is detectable by a refrigerant circuit has been proposed (for example, Patent Literature 1). In Patent Literature 1, for example, to achieve a state in which only a liquid refrigerant exists (a gas refrigerant does not exist) as a refrigerant that flows through a liquid pipe of a refrigerant circuit at the time of cooling cycle, a refrigerant amount is determined by using a degree of super-cooling of the refrigerant at an outlet of a condenser in a state in which a degree of super-heating of the refrigerant at an outlet of an evaporator or pressure of the evaporator is adjusted (hereinafter, this state will be referred to as a default state).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Laid-open Patent Publication No. 2006-23072

Summary

Technical Problem

[0004] When an air conditioner is actually operating, it is difficult to achieve the default state that is a prerequisite of Patent Literature 1, so that it becomes difficult to estimate a refrigerant amount.

[0005] In view of the foregoing situations, an object of the present invention is to provide an air conditional that is able to estimate a remaining refrigerant amount in a refrigerant circuit even when the air conditioner is actually operating.

Solution to Problem

[0006] According to an aspect of an embodiment, an air conditioner includes a refrigerant circuit that is formed by connecting, by a refrigerant pipe, an indoor unit including an indoor heat exchanger to an outdoor unit including a compressor, an outdoor heat exchanger, and an expansion valve. The refrigerant circuit is filled with a predetermined amount of a refrigerant. The air conditioner includes an acquisition unit, a storage unit, an estimation model, a detection unit and a control unit. The acquisition unit regularly acquires an operating state quantity at a time of air conditioning operation. The storage unit stores therein the operating state quantity that is acquired by the acquisition unit. The estimation model estimates a refrigerant remaining amount in the refrigerant circuit by using the operating state quantity. The detection unit detects, from the storage unit, one of a first operating state quantity and a second operating state quantity. The first operating state quantity is an operating state quantity in a state in which the refrigerant circuit meets a first stability condition. The second operating state quantity is an operating state quantity in a state in which the refrigerant circuit meets a second stability condition that is different from the first stability condition. The control unit estimates the remaining refrigerant amount in the refrigerant circuit by using the estimation model and the operating state quantity that is detected by the detection unit.

Advantageous Effects of Invention

[0007] According to one aspect, it is possible to estimate a remaining refrigerant amount in a refrigerant circuit even when an air conditioner is actually operating. Brief Description of Drawings

FIG. 1 is an explanatory diagram illustrating an example of an air conditioner of a present embodiment.
FIG. 2 is an explanatory diagram illustrating an example of an outdoor unit and an indoor unit.
FIG. 3 is a block diagram illustrating an example of a control circuit of the outdoor unit.
FIG. 4 is a Mollier diagram illustrating a state of a change of a refrigerant in the air conditioner.
FIG. 5 is a flowchart illustrating an example of processing operation performed by the control circuit in relation to an acquisition process.

FIG. 6 is a flowchart illustrating an example of processing operation performed by the control circuit in relation to a detection process.

FIG. 7 is a flowchart illustrating an example of processing operation performed by the control circuit in relation to an estimation process.

FIG. 8 is an explanatory diagram illustrating an air conditioning system of a second embodiment.

Description of Embodiments

[0008] Embodiments of an air conditioner and the like disclosed in the present application will be described in detail below based on the drawings. The disclosed technology is not limited by the present embodiments. In addition, each of the embodiments described below may be appropriately modified as long as no contradiction is derived.

First Embodiment

Configuration of air conditioner

[0009] FIG. 1 is an explanatory diagram illustrating an example of an air conditioner 1 of the present embodiment. The air conditioner 1 illustrated in FIG. 1 is, for example, a home-use air conditioner that includes a single outdoor unit 2 and a single indoor unit 3. The outdoor unit 2 is connected to the indoor unit 3 by a liquid pipe 4 and a gas pipe 5. Further, a refrigerant circuit 6 of the air conditioner 1 is formed by connecting the outdoor unit 2 and the indoor unit 3 by a refrigerant pipe, such as the liquid pipe 4 and the gas pipe 5.

Configuration of outdoor unit

[0010] FIG. 2 is an explanatory diagram illustrating an example of the outdoor unit 2 and the indoor unit 3. The outdoor unit 2 includes a compressor 11, a four-way valve 12, an outdoor heat exchanger 13, an expansion valve 14, an accumulator 15, an outdoor unit fan 16, and a control circuit 17. With use of the compressor 11, the four-way valve 12, the outdoor heat exchanger 13, the expansion valve 14, and the accumulator 15, an outdoor-side refrigerant circuit that constitutes a part of the refrigerant circuit 6 is formed by connecting these devices to one another by each of refrigerant pipes that will be described in detail below.

[0011] The compressor 11 is a variable-capacity compressor of a pressurized container type that is able to change working capacity in accordance with drive of a motor (not illustrated) for which a rotation speed is controlled by an inverter, for example. A refrigerant discharge side of the compressor 11 is connected to a first port 12A of the four-way valve 12 by a discharge pipe 21. Further, a refrigerant suction side of the compressor 11 is connected to a refrigerant outflow side of the accumulator 15 by a suction pipe 22.

[0012] The four-way valve 12 is a valve for changing a direction in which a refrigerant flows in the refrigerant circuit 6, and includes the first port 12A to a fourth port 12D. The first port 12A is connected to the refrigerant discharge side of the compressor 11 by the discharge pipe 21. A second port 12B is connected to one refrigerant gate (corresponding to a first outdoor heat exchange opening 13A to be described later) of the outdoor heat exchanger 13 by an outdoor refrigerant pipe 23. A third port 12C is connected to a refrigerant inflow side of the accumulator 15 by an outdoor refrigerant pipe 26. Further, the fourth port 12D is connected to an indoor heat exchanger 51 by an outdoor gas pipe 24.

[0013] The outdoor heat exchanger 13 performs heat exchange between the refrigerant and outdoor air that is taken into the outdoor unit 2 by rotation of the outdoor unit fan 16. The outdoor heat exchanger 13 includes the first outdoor heat exchange opening 13A that serves as the one refrigerant gate, a second outdoor heat exchange opening 13B that serves as another refrigerant gate, and an outdoor heat exchange intermediate part 13C that connects the first outdoor heat exchange opening 13A and the second outdoor heat exchange opening 13B. The first outdoor heat exchange opening 13A is connected to the second port 12B of the four-way valve 12 by the outdoor refrigerant pipe 23. The second outdoor heat exchange opening 13B is connected to the expansion valve 14 by an outdoor liquid pipe 25. The outdoor heat exchange intermediate part 13C is connected to the first outdoor heat exchange opening 13A and the second outdoor heat exchange opening 13B. The outdoor heat exchanger 13 functions as a condenser when the air conditioner 1 performs cooling operation, and functions as an evaporator when the air conditioner 1 performs heating operation.

[0014] The expansion valve 14 is an electronic expansion valve that is arranged on the outdoor liquid pipe 25 and that is driven by a pulse motor (not illustrated). The expansion valve 14 adjusts an amount of a refrigerant (an amount of a refrigerant that flows from the outdoor heat exchanger 13 to the indoor heat exchanger 51 or an amount of a refrigerant that flows from the indoor heat exchanger 51 to the outdoor heat exchanger 13) that flows from the expansion valve 14 into the refrigerant circuit 6, by adjusting a degree of opening in accordance with the number of pulses given to the pulse motor. The degree of opening of the expansion valve 14 is adjusted such that temperature at which the refrigerant is discharged (refrigerant discharge temperature) by the compressor 11 reaches target discharge temperature that is predetermined temperature.

[0015] The refrigerant inflow side of the accumulator 15 is connected to the third port 12C of the four-way valve 12 by the outdoor refrigerant pipe 26. Further, the refrigerant outflow side of the accumulator 15 is connected to a refrigerant inflow side of the compressor 11 by the suction pipe 22. The accumulator 15 separates the refrigerant, which has flown from the outdoor refrigerant pipe 26 into the accumulator 15, into a gas refrigerant and a liquid refrigerant, and causes only the gas refrigerant to be sucked by the compressor 11.

[0016] The outdoor unit fan 16 is made of a resin material and is arranged in the vicinity of the outdoor heat exchanger 13. The outdoor unit fan 16 takes outdoor air into the outdoor unit 2 from a suction opening (not illustrated) in accordance with rotation of a fan motor (not illustrated), and discharges the outdoor air that is subjected to heat exchange with the refrigerant in the outdoor heat exchanger 13 to outside of the outdoor unit 2 via a discharge opening (not illustrated).

[0017] Furthermore, a plurality of sensors are arranged in the outdoor unit 2. In the discharge pipe 21, a discharge temperature sensor 31 that detects temperature of the refrigerant that is discharged from the compressor 11, that is, the refrigerant discharge temperature, is arranged. In the outdoor liquid pipe 25 between the outdoor heat exchanger 13 and the expansion valve 14, an outdoor heat exchange outlet sensor 32 that detects temperature of the refrigerant that flows into the second outdoor heat exchange opening 13B or temperature of the refrigerant that flows out of the second outdoor heat exchange opening 13B among temperature of the heat exchanger is arranged. Moreover, in the vicinity of the suction opening (not illustrated) of the outdoor unit 2, an outdoor air temperature sensor 33 that detects temperature of the outdoor air that flows into the outdoor unit 2, that is, outdoor air temperature, is arranged.

[0018] The control circuit 17 controls the outdoor unit 2 upon receiving an instruction from a control circuit 18 of the indoor unit 3 to be described later. The control circuit 17 of the outdoor unit 2 includes a communication unit, a storage unit, and a control unit (not illustrated). The communication unit is a communication interface for communicating with a communication unit 41 of the indoor unit 3 to be described later. The storage unit is, for example, a flash memory, and stores therein a control program of the outdoor unit 2, operating state quantities, such as detected values, corresponding to detection signals from various sensors, a driving state of the compressor 11 or the outdoor unit fan 16, a rated capacity of the outdoor unit 2, a requested capacity of each of the indoor units 3, and the like.

Configuration of indoor unit

[0019] As illustrated in FIG. 2, the indoor unit 3 includes the indoor heat exchanger 51, a gas pipe connection unit 52, a liquid pipe connection unit 53, an indoor unit fan 54, and the control circuit 18. The indoor heat exchanger 51, the gas pipe connection unit 52, and the liquid pipe connection unit 53 are connected to one another by each of refrigerant pipes to be described later, and form an indoor refrigerant circuit that constitutes a part of the refrigerant circuit 6.

[0020] The indoor heat exchanger 51 performs heat exchange between the refrigerant and indoor air that is taken into the indoor unit 3 from a suction opening (not illustrated) by rotation of the indoor unit fan 54. The indoor heat exchanger 51 includes a first indoor heat exchange opening 51A that serves as one refrigerant gate, a second indoor heat exchange opening 51B that serves as another refrigerant gate, and an indoor heat exchange intermediate part 51C that connects the first indoor heat exchange opening 51A and the second indoor heat exchange opening 51B. The first indoor heat exchange opening 51A is connected to the gas pipe connection unit 52 by an indoor gas pipe 56. The second indoor heat exchange opening 51B is connected to the liquid pipe connection unit 53 by an indoor liquid pipe 57. The indoor heat exchange intermediate part 51C is connected to the first indoor heat exchange opening 51A and the second indoor heat exchange opening 51B. The indoor heat exchanger 51 functions as a condenser when the air conditioner 1 performs heating operation, and functions as an evaporator when the air conditioner 1 performs cooling operation.

[0021] The indoor unit fan 54 is made of a resin material and is arranged in the vicinity of the indoor heat exchanger 51. The indoor unit fan 54 takes indoor air into the indoor unit 3 from a suction opening (not illustrated) in accordance with rotation of a fan motor (not illustrated), and discharges the indoor air that is subjected to heat exchange with the refrigerant in the indoor heat exchanger 51 to inside of a room from a discharge opening (not illustrated).

[0022] Various sensors are arranged in the indoor unit 3. In the indoor heat exchange intermediate part 51C, an indoor heat exchange intermediate sensor 58 that detects temperature of the refrigerant that passes through the indoor heat exchange intermediate part 51C, that is, indoor heat exchange intermediate temperature, among temperature of the heat exchanger is arranged.

[0023] The control circuit 18 controls the entire air conditioner 1. FIG. 3 is a block diagram illustrating an example of the control circuit 18 of the indoor unit 3. The control circuit 18 includes the communication unit 41, an acquisition unit 42, a detection unit 43, a storage unit 44, and a control unit 45. The communication unit 41 is a communication interface for communicating with the communication unit of the outdoor unit 2. The acquisition unit 42 acquires operating state quantities, such as detected values, corresponding to detection signals from the various sensors as described above. The storage unit 44 is, for example, a flash memory, and stores therein a control program of the indoor unit 3, the operating state quantities, such as detected values, corresponding to detection signals from various sensors, a driving state of the indoor unit fan 54, operation information (for example, including information on operation and stop of the compressor 11, a driving state of the outdoor unit fan 16, and the like) that is transmitted from the outdoor unit 2, the rated capacity of the outdoor unit 2, the requested capacity of each of the indoor units 3, and the like.

[0024] The storage unit 44 includes an operating state quantity memory 61, a first operating state quantity memory 61A, and a second operating state quantity memory 61B. The operating state quantity memory 61 stores therein all operating state quantities that are acquired by the acquisition unit 42. The operating state quantities are, for example, operating state quantities at the time of cooling operation, such as rotation speed of the compressor 11, the degree of opening of the expansion valve 14, the refrigerant discharge temperature of the compressor 11, the outdoor heat exchange outlet temperature, and temperature of outdoor air, or operating state quantities at the time of heating operation, such as the rotation speed of the compressor 11, the degree of opening of the expansion valve 14, the refrigerant discharge temperature of the compressor 11, and the indoor heat exchange intermediate temperature.

[0025] The first operating state quantity memory 61A stores therein a first operating state quantity among the operating state quantities. The first operating state quantity is an operating state quantity that indicates an operating state at the time of air conditioning operation in a state in which a first stability condition is met under the circumstances in which the refrigerant stably circulates inside the refrigerant circuit 6 while each of values of high pressure and low pressure in the refrigerant circuit 6 is stable. The first stability condition is that a certain state, in which variation of the rotation speed of the compressor 11 falls within a first predetermined range, continues for a first predetermined period or more, and that a certain state, in which an absolute value of a difference between the refrigerant discharge temperature and the target discharge temperature of the compressor 11 is equal to or smaller than a predetermined value, continues for the first predetermined period or more. The first operating state quantity is, for example, an operating state quantity that is acquired when the variation of the rotation speed of the compressor 11 is within ±1 rps during five minutes and when the absolute value of the difference between the refrigerant discharge temperature and the target temperature of the compressor 11 falls within ±2°C during five minutes, after a lapse of eight minutes since activation of the compressor 11.

[0026] The second operating state quantity memory 61B stores therein a second operating state quantity among the operating state quantities. The second operating state quantity is an operating state quantity that indicates an operating state at the time of air conditioning operation in a state in which a second stability condition that is different from the first stability condition is met under the circumstances in which the refrigerant stably circulates inside the refrigerant circuit 6. The second stability condition is that a certain state, in which the variation of the rotation speed of the compressor 11 falls within a second predetermined range that exceeds the first predetermined range, continues for the first predetermined period or more or for a second predetermined period, which exceeds the first predetermined period, or more. The second operating state quantity is, for example, an operating state quantity that is acquired when the variation of the rotation speed of the compressor 11 is within ±5 rps during 12 minutes, after a lapse of eight minutes since activation of the compressor 11. Meanwhile, the second stability condition is a condition in which further variation of the rotation speed of the compressor 11 is allowed as compared to the first stability condition, and therefore, the second operating state quantity that is acquired under the second stability condition varies as compared to the first operating state quantity that is acquired under the first stability condition.

[0027] The detection unit 43 detects the first operating state quantity from among the operating state quantities stored in the operating state quantity memory 61, and stores the detected first operating state quantity in the first operating state quantity memory 61A. Further, the detection unit 43 detects the second operating state quantity from among the operating state quantities stored in the operating state quantity memory 61, and stores the detected second operating state quantity in the second operating state quantity memory 61B.

[0028] Furthermore, the storage unit 44 stores therein an estimation model for estimating a remaining refrigerant amount in the refrigerant circuit 6. The estimation model includes a cooling estimation model 62A and a heating estimation model 62B. The cooling estimation model 62A is a model for estimating the remaining refrigerant amount in the refrigerant circuit 6 at the time of cooling operation. Further, the heating estimation model 62B is a model for estimating the remaining refrigerant amount in the refrigerant circuit 6 at the time of heating operation.

[0029] The control unit 45 loads the detected values of the various sensors at regular time intervals (for example, every 30 seconds). The control unit 45 controls the entire air conditioner 1 based on the various kinds of input information. Further, the control unit 45 estimates the remaining refrigerant amount by using each of the estimation models as described above.

[0030] Furthermore, the control unit 45 counts the number of detections of the first operating state quantity in a predetermined period, and estimates the remaining refrigerant amount in the refrigerant circuit 6 by using the first operating state quantity and each of the estimation models if the number of detections of the first operating state quantity is equal to or larger than a predetermined value. If the number of detections of the first operating state quantity is smaller than the predetermined value in the predetermined period, the control unit 45 estimates the remaining refrigerant amount in the refrigerant circuit 6 by using the second operating state quantity and each of the estimation models. For example, if the number of detections of the first operating state quantity in the predetermined period, such as one day, is equal to or larger than the predetermined value, such as 50, the control unit 45 estimates the remaining refrigerant amount by using the first operating state quantity and each of the estimation models. Further, if the number of detections of the first operating state quantity in one day is smaller than 50, the control unit 45 estimates the remaining refrigerant amount by using the second operating state quantity and each of the estimation models.

[0031] The control unit 45 estimates, at a predetermined time, such as at one o'clock in the morning, in one day, the remaining refrigerant amount in the refrigerant circuit 6 of a previous day by using the first operating state quantities or the second operating state quantities that are acquired in 24 hours of the previous day. If the number of detections of the first operating state quantity is equal to or larger than the predetermined value, the remaining refrigerant amount is estimated by using the acquired first operating state quantities and the estimation models, and, if the number of detections of the first operating state quantity is smaller than the predetermined value, the remaining refrigerant amount is estimated by using the acquired second operating state quantities and the estimation models. Meanwhile, a specific method of estimating the remaining refrigerant amount in one day will be described later.

Operation of refrigerant circuit

[0032] A flow of the refrigerant in the refrigerant circuit 6 and operation of each of the units when the air conditioner 1 according to the present embodiment performs air conditioning operation will be described below.

[0033] If the air conditioner 1 performs heating operation, the four-way valve 12 is switched such that the first port 12A and the fourth port 12D communicate with each other and the second port 12B and the third port 12C communicate with each other (a state indicated by bold lines in FIG. 2). With this configuration, the refrigerant circuit 6 enters a heating cycle in which the indoor heat exchanger 51 functions as the condenser and the outdoor heat exchanger 13 functions as the evaporator. Meanwhile, for convenience of explanation, the flow of the refrigerant at the time of heating operation is indicated by bold arrows in FIG. 2.

[0034] If the compressor 11 drives while the refrigerant circuit 6 is in the state as described above, the refrigerant that is discharged from the compressor 11 flows through the discharge pipe 21, flows into the four-way valve 12, flows through the outdoor gas pipe 24 via the four-way valve 12, and flows into the gas pipe 5. The refrigerant that has flown through the gas pipe 5 flows into the indoor unit 3 via the gas pipe connection unit 52. The refrigerant that has flown into the indoor unit 3 flows through the indoor gas pipe 56 and flows into the indoor heat exchanger 51. The refrigerant that has flown into the indoor heat exchanger 51 is subjected to heat exchange with indoor air that is taken into the indoor unit 3 by rotation of the indoor unit fan 54, and therefore condenses. In other words, the indoor heat exchanger 51 functions as the condenser and the indoor air that is heated by heat exchange with the refrigerant in the indoor heat exchanger 51 is blown out to the inside of the room via a discharge port (not illustrated), so that the inside of a room in which the indoor unit 3 is installed is heated.

[0035] The refrigerant that has flown from the indoor heat exchanger 51 to the indoor liquid pipe 57 flows out to the liquid pipe 4 via the liquid pipe connection unit 53. The refrigerant that has flown into the liquid pipe 4 flows into the outdoor unit 2. The refrigerant that has flown into the outdoor unit 2 flows through the outdoor liquid pipe 25 and is decompressed by passing through the expansion valve 14. The refrigerant that is decompressed by the expansion valve 14 flows through the outdoor liquid pipe 25, flows into the outdoor heat exchanger 13, is subjected to heat exchange with outdoor air that has flown in from the suction opening (not illustrated) of the outdoor unit 2 by the rotation of the outdoor unit fan 16, and evaporates. The refrigerant that has flown out to the outdoor refrigerant pipe 26 from the outdoor heat exchanger 13 sequentially flows into the four-way valve 12, the outdoor refrigerant pipe 26, the accumulator 15, and the suction pipe 22, is sucked by the compressor 11, is compressed again, and flows out to the outdoor gas pipe 24 via the first port 12A and the fourth port 12D of the four-way valve 12.

[0036] Furthermore, when the air conditioner 1 performs cooling operation, the four-way valve 12 is switched such that the first port 12A and the second port 12B communicate with each other and the third port 12C and the fourth port 12D communicate with each other (a state indicated by dashed lines in FIG. 2). With this configuration, the refrigerant circuit 6 enters a cooling cycle in which the indoor heat exchanger 51 functions as the evaporator and the outdoor heat exchanger 13 functions as the condenser. Meanwhile, for convenience of explanation, the flow of the refrigerant at the time of cooling operation is indicated by dashed-line arrows in FIG. 2.

[0037] If the compressor 11 drives while the refrigerant circuit 6 is in the state as described above, the refrigerant that is discharged from the compressor 11 flows through the discharge pipe 21, flows into the four-way valve 12, flows through the outdoor refrigerant pipe 23 via the four-way valve 12, and flows into the outdoor heat exchanger 13. The refrigerant that has flown into the outdoor heat exchanger 13 is subjected to heat exchange with outdoor air that is taken into the outdoor unit 2 by rotation of the outdoor unit fan 16, and condenses. In other words, the outdoor heat exchanger 13 functions as the condenser, and the outdoor air that is heated by the refrigerant in the outdoor heat exchanger 13 is blown out to the outside of the room from a discharge port (not illustrated).

[0038] The refrigerant that has flown into the outdoor liquid pipe 25 from the outdoor heat exchanger 13 is decompressed by passing through the expansion valve 14. The refrigerant that is decompressed by the expansion valve 14 flows through the liquid pipe 4 and flows into the indoor unit 3. The refrigerant that has flown into the indoor unit 3 flows through the indoor liquid pipe 57, flows into the indoor heat exchanger 51, is subjected to heat exchange with indoor air that has flown in from the suction opening (not illustrated) of the indoor unit 3 by the rotation of the indoor unit fan 54, and evaporates. In other words, the indoor heat exchanger 51 functions as the evaporator, and the indoor air that is cooled by heat exchange with the refrigerant in the indoor heat exchanger 51 is blown out to the inside of the room via a discharge port (not illustrated), so that the inside of the room in which the indoor unit 3 is installed is cooled.

[0039] The refrigerant that flows from the indoor heat exchanger 51 to the gas pipe 5 via the gas pipe connection unit 52 flows through the outdoor gas pipe 24 of the outdoor unit 2 and flows into the fourth port 12D of the four-way valve 12. The refrigerant that has flown into the fourth port 12D of the four-way valve 12 flows into the refrigerant inflow side of the accumulator 15 via the third port 12C. The refrigerant that has flown in from the refrigerant inflow side of the accumulator 15 flows in via the suction pipe 22, is sucked by the compressor 11, and is compressed again.

[0040] While the air conditioner 1 is performing the cooling operation or the heating operation as described above, the acquisition unit 42 in the control circuit 18 acquires sensor values of the discharge temperature sensor 31, the outdoor heat exchange outlet sensor 32, and the outdoor air temperature sensor 33 via the control circuit 17 of the outdoor unit 2. Furthermore, the acquisition unit 42 acquires sensor values of the indoor heat exchange intermediate sensor 58 and a suction temperature sensor 59 of the indoor unit 3.

[0041] FIG. 4 is a Mollier diagram illustrating a cooling cycle of the air conditioner 1. As described above, when the air conditioner 1 performs the cooling operation, the outdoor heat exchanger 13 functions as the condenser and the indoor heat exchanger 51 functions as the evaporator, and when the air conditioner 1 performs the heating operation, the outdoor heat exchanger 13 functions as the evaporator and the indoor heat exchanger 51 functions as the condenser.

[0042] The compressor 11 compresses a low-temperature and low-pressure gas refrigerant (a refrigerant in a state at a point A in FIG. 4) that flows in from the evaporator, and discharges a high-temperature and high-pressure gas refrigerant (a refrigerant in a state at a point B in FIG. 4). Meanwhile, temperature of the gas refrigerant that is discharged by the compressor 11 is refrigerant discharge temperature, and the refrigerant discharge temperature is detected by the discharge temperature sensor 31.

[0043] The condenser performs heat exchange between the high-temperature and high-pressure gas refrigerant flown from the compressor 11 and air, and condenses the high-temperature and high-pressure gas refrigerant. At this time, in the condenser, the entire gas refrigerant changes to a liquid refrigerant due to a latent heat change, and thereafter, temperature of the liquid refrigerant decreases due to a sensible heat change and the refrigerant enters a super-cooled state (a state at a point C in FIG. 4). Meanwhile, temperature at which the gas refrigerant changes to the liquid refrigerant due to the latent heat change is condensation temperature, and temperature of the refrigerant in the super-cooled state at an outlet of the condenser is heat exchange outlet temperature. The heat exchange outlet temperature among the heat exchanger temperature is detected by the outdoor heat exchange outlet sensor 32 at the time of cooling operation. Meanwhile, at the time of heating operation, the refrigerant flows in an opposite direction of the refrigerant in the cooling operation and the outdoor heat exchanger 13 functions as the evaporator. At the time of heating operation, the outdoor heat exchange outlet sensor 32 is used to detect the temperature of the outdoor heat exchanger 13 and detect freezing or used to control defrosting operation.

[0044] The expansion valve 14 decompresses the low-temperature and high-pressure refrigerant that is flown out of the condenser. The refrigerant that is decompressed by the expansion valve 14 becomes a gas-liquid two-phase refrigerant in which gas and liquid are mixed (a refrigerant in a state at a point D in FIG. 4).

[0045] The evaporator performs heat exchange between the gas-liquid two-phase refrigerant that has flown in and air, and evaporates the refrigerant. At this time, in the evaporator, the entire gas-liquid two-phase refrigerant changes to a gas refrigerant due to a latent heat change, and thereafter, temperature of the gas refrigerant increases due to a sensible heat change and the gas refrigerant enters a super-heated state (the state at the point A in FIG. 4) and is sucked by the compressor 11. Meanwhile, temperature at which the liquid refrigerant changes to the gas refrigerant due to the latent heat change is evaporation temperature. The evaporation temperature is indoor heat exchange intermediate temperature that is detected by the indoor heat exchange intermediate sensor 58 at the time of cooling operation. Furthermore, temperature of the refrigerant that is super-heated by the evaporator and sucked by the compressor 11 is suction temperature. Meanwhile, at the time of heating operation, the refrigerant flows in an opposite direction of the refrigerant in the cooling operation, and the indoor heat exchanger 51 functions as the condenser. A detection result of the indoor heat exchange intermediate sensor 58 is used to calculate the target discharge temperature.

Configuration of estimation model

[0046] The estimation model is generated by a multiple regression analysis method that is one of regression analysis methods by using an arbitrary operating state quantity (feature value) among a plurality of operating state quantities. In the multiple regression analysis method, the estimation model is generated by selecting a regression equation, in which a P value (a value indicating a degree of influence of the operating state quantity on accuracy of the generated estimation model (predetermined weight parameter)) is minimum and a correction value R2 (a value indicating accuracy of the generated estimation model) is maximum in a range from 0.9 to 1.0, from among regression equations that are obtained from a test result using an actual air conditioner (hereinafter, an actual device) (the test result is a result of a test that is performed by the actual device to examine what value of the operating state quantity is obtained when the remaining refrigerant amount in the refrigerant circuit is changed) or from among regression equations that are obtained from a plurality of simulation results (results of calculation of a value of the operating state quantity with respect to the remaining refrigerant amount, by reproduction of the refrigerant circuit by numerical calculation). Here, the P value and the correction value R2 are values related to the accuracy of the estimation model when the estimation model is generated by the multiple regression analysis method, and the accuracy of the generated estimation model increases as the P value decreases and the correction value R2 approaches 1.0.

[0047] The estimation model includes the cooling estimation model 62A and the heating estimation model 62B. In the present embodiment, each of the estimation models is generated by using a test result that is obtained by using an actual device as will be described later, and is stored in the control circuit 18 of the air conditioner 1 in advance.

[0048] The cooling estimation model 62A is a first regression equation that is able to estimate the remaining refrigerant amount at the time of cooling operation with high accuracy by using the operating state quantity, such as the first operating state quantity or the second operating state quantity, at the time of cooling operation.

$$\text{First regression equation} = (\alpha 1 \times \text{rotation speed of compressor}) + (\alpha 2 \times \text{degree of opening of expansion valve}) + (\alpha 3 \times \text{discharge temperature of compressor}) + (\alpha 4 \times \text{heat exchange outlet temperature}) + (\alpha 5 \times \text{outdoor air temperature}) + \alpha 6 \quad (1)$$

[0049] It is assumed that coefficients $\alpha 1$ to $\alpha 6$ are determined when the estimation model is generated. The control unit 45 assigns, at a predetermined time in one day, each of the rotation speed of the compressor 11, the degree of opening of the expansion valve 14, the refrigerant discharge temperature of the compressor 11, the heat exchange outlet temperature, and the outdoor air temperature among the first operating state quantities or the second operating state quantities, which are detected by the detection unit 43 during 24 hours of the previous day, to the first regression equation, and calculates the remaining refrigerant amounts in the refrigerant circuit 6 at time points at which the first operating state quantities or the second operating state quantities are detected. Further, the control unit 45 adopts, as an estimated value of the remaining refrigerant amount of the previous day, one of an average value of the remaining refrigerant amounts calculated by using the first operating state quantities at the respective time points and an average value of the remaining refrigerant amounts calculated using the second operating state quantities at the respective time points. Meanwhile, the reason that each of the rotation speed of the compressor 11, the degree of opening of the expansion valve, the refrigerant discharge temperature of the compressor 11, the outdoor heat exchange outlet temperature, and the outdoor air temperature is assigned is to use the feature value that is used when the cooling estimation model 62A is generated. The rotation speed of the compressor 11 is detected by, for example, a rotation speed sensor (not illustrated) of the compressor 11. As the degree of opening of the expansion valve, for example, the number of pulses of a pulse signal that is input from the control unit 45 to a stepping motor (not illustrated) of the expansion valve is used. The refrigerant discharge temperature of the compressor 11 is detected by the discharge temperature sensor 31. The heat exchange outlet temperature is detected by the outdoor heat exchange outlet sensor 32. The outdoor air temperature is detected by the outdoor air temperature sensor 33.

[0050] The heating estimation model 62B is a second regression equation that is able to estimate the remaining refrigerant amount at the time of heating operation with high accuracy by using the operating state quantity, such as the first operating state quantity or the second operating state quantity, at the time of heating operation.

$$\text{Second regression equation} = (\alpha 11 \times \text{rotation speed of compressor}) + (\alpha 12 \times \text{degree of opening of expansion valve}) + (\alpha 13 \times \text{discharge temperature of compressor}) + (\alpha 14 \times \text{indoor heat exchange intermediate temperature}) + \alpha 15 \quad (2)$$

[0051] It is assumed that coefficients $\alpha 11$ to $\alpha 15$ are determined when the estimation model is generated. The control unit 45 assigns, at a predetermined time in one day, each of the rotation speed of the compressor 11, the degree of opening of the expansion valve 14, the refrigerant discharge temperature of the compressor 11, and the indoor heat exchange intermediate temperature among the first operating state quantities or the second operating state quantities, which are detected by the detection unit 43 during 24 hours of the previous day, to the second regression equation, and calculates the remaining refrigerant amounts in the refrigerant circuit 6 at time points at which the first operating state quantities or the second operating state quantities are detected. Further, the control unit 45 adopts, as an estimated value of the remaining refrigerant amount of the previous day, one of an average value of the remaining refrigerant amounts calculated by using the first operating state quantities at the respective time points and an average value of the remaining refrigerant amounts calculated using the second operating state quantities at the respective time points. Meanwhile, the reason that each of the rotation speed of the compressor 11, the degree of opening of the expansion valve, the refrigerant discharge temperature of the compressor 11, and the indoor heat exchange intermediate temperature is assigned is to use the feature value that is used when the heating estimation model 62B is generated. The rotation speed of the compressor 11 is detected by the rotation speed sensor (not illustrated) of the compressor 11. As the degree of opening of the expansion valve, for example, the number of pulses of a pulse signal that is input from the control unit 45 to a stepping motor (not illustrated) of the expansion valve is used. The refrigerant discharge temperature of the compressor 11 is detected by the discharge temperature sensor 31. The indoor heat exchange intermediate temperature among the heat exchanger temperature is detected by the indoor heat exchange intermediate sensor 58.

[0052] As described above, the remaining refrigerant amount is estimated by using the first regression equation at the time of cooling operation. Further, the remaining refrigerant amount is estimated by using the second regression equation at the time of heating operation.

Method of generating regression equations

[0053] The feature value that is used to generate the first regression equation and the second regression equation will be described below. At the time of cooling operation in which the first regression equation is used, in the present embodiment, each of the operating state quantities, such as the rotation speed of the compressor 11, the degree of opening of the expansion valve 14, the refrigerant discharge temperature of the compressor 11, the outdoor heat exchange outlet temperature, and the outdoor air temperature, is used as the feature value that is used when the first regression equation is generated by the multiple regression analysis method. Further, a test result using an actual device is used as each of the operating state quantities. Furthermore, at the time of heating operation in which the second regression equation is used, in the present embodiment, each of the operating state quantities, such as the rotation speed of the compressor 11, the degree of opening of the expansion valve 14, the refrigerant discharge temperature of the compressor 11, and the indoor heat exchange intermediate temperature, is used as the feature value that is used when the second regression equation is generated by the multiple regression analysis. Moreover, a test result using an actual device is used as each of the operating state quantities. Meanwhile, when the first regression equation that is the cooling estimation model 62A or the second regression equation that is the heating estimation model 62B as described above is generated, the first operating state quantity that is detected when the first stability condition is met is used.

[0054] Specifically, at a design stage of the air conditioner 1, as one example, the air conditioner 1 is subjected to test drive by changing outdoor air temperature, indoor temperature, and a refrigerant storage amount while the indoor unit 3 is operating, and a relationship between the feature value and a refrigerant shortage rate is acquired. As a condition under which the test drive is performed, for example, the outdoor air temperature is changed to 20°C, 25°C, 30°C, 35°C, and 40°C. Meanwhile, when the test drive is performed, it may be possible to add a different parameter of the outdoor air temperature.

[0055] Among the plurality of operating state quantities, an arbitrary operating state quantity (feature value) that is used for the estimation model is obtained from a test result (hereinafter, referred to as teacher data) that indicates a relationship between the plurality of operating state quantities and the refrigerant storage amount. Specifically, the teacher data is data (teacher data that is used to generate the estimation model by the multiple regression analysis method) in which the remaining refrigerant amount, which is changed by changing a refrigerant amount stored in the refrigerant circuit, and each of the operating state quantities that are obtained when the operation is performed with the changed remaining refrigerant amount are associated with each other.

[0056] In the multiple regression analysis method, for example, the test drive is performed while changing the refrigerant storage amount, each of the operating state quantities that vary for each outside air temperature with respect to each refrigerant storage amount, and data classification is performed for each refrigerant storage amount. Examples of the operating state quantity that is used as the teacher data include the operating state quantities of the compressor 11, the indoor unit 3, and the outdoor unit 2. Examples of the operating state quantity of the compressor 11 include the rotation speed, a target rotation speed, an operating time, the refrigerant discharge temperature, the target discharge temperature, and output voltage. Furthermore, examples of the operating state quantity of the indoor unit 3 include a rotation speed and a target rotation speed of the indoor unit fan 54, and the heat exchanger intermediate sensor temperature. Moreover, examples of the operating state quantity of the outdoor unit 2 include a rotation speed and a target rotation speed of the outdoor unit fan 16, the degree of opening of the expansion valve 14, and sensor temperature at the outlet of the condenser. Furthermore, by performing machine learning by using the data for each refrigerant storage amount as the teacher data, an arbitrary operating state quantity (feature value) for estimating the remaining refrigerant amount is extracted, coefficients are derived, and the estimation model is generated.

Operation of process of acquiring operating state quantity

[0057] Operation at the time of acquiring the operating state quantity by the air conditioner 1 of the first embodiment will be described below. FIG. 5 is a flowchart illustrating an example of the processing operation performed by the control circuit 18 in relation to acquisition of the operating state quantity. In FIG. 5, the acquisition unit 42 of the control circuit 18 determines whether a predetermined timing for acquiring the operating state quantity has come (Step S11). Meanwhile, the predetermined timing is a timing that comes in five-minute intervals for acquiring the operating state quantity, for example. If the predetermined timing has come (Step S11: Yes), the acquisition unit 42 acquires the operating state quantity of the air conditioner 1 (Step S12). After acquiring the operating state quantity of the air conditioner 1, the acquisition unit 42 stores the operating state quantity in the operating state quantity memory 61 (Step S13), and returns the process to Step S11. Meanwhile, if the predetermined timing has not come at Step S11 (Step S11: No), the acquisition unit 42 returns the process to Step S11.

Operation of process of detecting operating state quantity

[0058] FIG. 6 is a flowchart illustrating an example of the processing operation performed by the control circuit 18 in relation to detection the operating state quantity. In FIG. 6, the detection unit 43 of the control circuit 18 refers to, at a predetermined time (for example, at one o'clock in the morning as described above) in one day, the operating state quantities that are stored in the operating state quantity memory 61, and determines whether an operating state quantity that is acquired after a lapse of eight minutes since activation of the compressor 11 is present in the operating state quantity memory 61 (Step S21). If the operating state quantity that is acquired after a lapse of eight minutes since activation of the compressor 11 is present (Step S21: Yes), the detection unit 43 determines whether an operating state quantity that is acquired when a certain state, in which variation of the rotation speed of the compressor 11 falls within a second predetermined range, such as ±5 rps, continues for a second predetermined period, such as 12 minutes, or more, that is, when the second stability condition is met, is present in the operating state quantity memory 61 (Step S22). Meanwhile, timestamps that indicate acquisition times are added to the operating state quantities that are acquired at timings in five-minute intervals and that are stored in the operating state quantity memory 61, and the detection unit 43 is able to determine whether an operating state quantity that is acquired in a time period in which the second stability condition is met is present by referring to the timestamps that are added to the operating state quantities.

[0059] If the operating state quantity that is acquired when the certain state, in which the variation of the rotation speed of the compressor 11 falls within the second predetermined range, continues for the second predetermined period or more is not present in the operating state quantity memory 61 (Step S22: No), the detection unit 43 determines whether an operating state quantity that is acquired when a certain state, in which the variation of the rotation speed of the compressor 11 falls within the first predetermined range, such as ±1 rps, continues for the first predetermined period, such as 5 minutes, or more, is present in the operating state quantity memory 61 (Step S23). If the operating state quantity that is acquired when the certain state, in which the variation of the rotation speed of the compressor 11 falls within the first predetermined range, continues for the first predetermined period or more is present in the operating state quantity memory 61 (Step S23: Yes), the detection unit 43 determines whether an operating state quantity that is acquired when a certain state, in which an absolute value of a difference between the refrigerant discharge temperature and the target discharge temperature of the compressor 11 is equal to or smaller than a predetermined value, such as 2°C, continues for the first predetermined period or more is present among the operating state quantities that meet the condition at Step S23 (Step S24). In other words, the detection unit 43 performs the determination at Step S23 and the determination at Step S24, and determines whether the operating state quantity that is acquired when the first stability condition is met is present in the operating state quantity memory 61. Meanwhile, the detection unit 43 is able to determine whether the operating state quantity that is acquired in a time period in which the first stability condition is met is present by referring to the timestamps that are added to the operating state quantities.

[0060] If the operating state quantity that is acquired when the certain state, in which the absolute value between the refrigerant discharge temperature and the target discharge temperature of the compressor 11 is equal to or smaller than the predetermined value, continues for the first predetermined period or more is present among the operating state quantities that meet the condition at Step S23 (Step S24: Yes), the detection unit 43 detects the corresponding operating state quantity as the first operating state quantity (Step S25). Further, the detection unit 43 stores the first operating state quantity that is detected at Step S25 in the first operating state quantity memory 61A (Step S26), and returns the process to Step S21.

[0061] Furthermore, if the operating state quantity that is acquired when the certain state, in which the variation of the rotation speed of the compressor 11 falls within the second predetermined range, continues for the second predetermined period or more is present in the operating state quantity memory 61 (Step S22: Yes), the detection unit 43 detects the corresponding operating state quantity as the second operating state quantity (Step S27). The detection unit 43 stores the second operating state quantity that is detected at Step S27 in the second operating state quantity memory 61B (Step S28), and the process goes to Step S23.

[0062] Moreover, if the operating state quantity that is acquired after a lapse of eight minutes since activation of the compressor 11 is not present in the operating state quantity memory 61 (Step S21: No), the detection unit 43 returns the process to Step S21. Furthermore, if the operating state quantity that is acquired when the certain state, in which the variation of the rotation speed of the compressor 11 falls within the first predetermined range, continues for the first predetermined period or more is not present in the operating state quantity memory 61 (Step S23: No), the detection unit 43 returns the process to Step S21. Moreover, if the operating state quantity that is acquired when the certain state, in which the absolute value of the difference between the refrigerant discharge temperature and the target discharge temperature of the compressor 11 is equal to or smaller than the predetermined value, continues for the first predetermined period or more is not present among the operating state quantities that meet the condition at Step S23 (Step S24: No), the detection unit 43 returns the process to Step S21.

Operation of process of estimating remaining refrigerant amount

[0063] FIG. 7 is a flowchart illustrating an example of processing operation performed by the control circuit 18 in relation to estimation of the remaining refrigerant amount. In FIG. 7, the control unit 45 of the control circuit 18 determines whether the estimation timing has come (Step S31). Meanwhile, the estimation timing is the predetermined time in one day, such as at one o'clock in the morning, for example. If the estimation timing has come (Step S31: Yes), the control unit 45 counts the number of the first operating state quantities (the number of detections) acquired in a predetermined period, such as a previous day (Step S32), and determines whether the number of detections of the first operating state quantity in the predetermined period is equal to or larger than a predetermined number, for example, 50 (Step S33).

[0064] If the number of detections of the first operating state quantity in the predetermined period is equal to or larger than the predetermined value (Step S33: Yes), the control unit 45 calculates a remaining refrigerant amount in the refrigerant circuit 6 for each of the acquired first operating state quantities by using the first operating state quantities and each of the estimation models (Step S34). For example, the control unit 45 at the time of cooling operation calculates the remaining refrigerant amount in the refrigerant circuit 6 for each of the acquired first operating state quantities by using the first operating state quantities and the cooling estimation model 62A. Furthermore, the control unit 45 at the time of heating operation calculates the remaining refrigerant amount in the refrigerant circuit 6 for each of the acquired first operating state quantities by using the first operating state quantity and the heating estimation model 62B.

[0065] If the number of detections of the first operating state quantity in the predetermined period is not equal to or larger than the predetermined value (Step S33: No), that is, if the number of detections is smaller than the predetermined value, the control unit 45 calculates the remaining refrigerant amount in the refrigerant circuit 6 for each of the acquired second operating state quantities by using the second operating state quantities and the estimation model (Step S35). For example, the control unit 45 at the time of cooling operation calculates the remaining refrigerant amount in the refrigerant circuit 6 for each of the second operating state quantities by using the acquired second operating state quantities and the cooling estimation model 62A. Furthermore, the control unit 45 at the time of heating operation calculates the remaining refrigerant amount in the refrigerant circuit 6 for each of the acquired second operating state quantities by using the second operating state quantities and the heating estimation model 62B.

[0066] Subsequently, the control unit 45 calculates an average value of the remaining refrigerant amounts that are calculated at Step S34 or the remaining refrigerant amounts that are calculated at Step S35 (Step S36), and determines whether the calculated average value of the remaining refrigerant amounts is smaller than a predetermined value (Step S37). Here, a predetermined value is a value for which it is determined, by a test or the like that is performed in advance, that air conditioning performance of the air conditioner 1 is affected if the remaining refrigerant amount in the refrigerant circuit 6 becomes smaller than the predetermined value, and is, for example, 60% of a refrigerant amount that is stored in the refrigerant circuit 6 when the air conditioner 1 is installed.

[0067] If the calculated average value of the remaining refrigerant amounts is smaller than the predetermined value (Step S37: Yes), the control unit 45 outputs the calculated average value as an estimated value of the remaining refrigerant amount (Step S38), and returns the process to Step S31. Here, output of the estimated value of the remaining refrigerant amount is transmission of the estimated value of the remaining refrigerant amount to, for example, a remote controller (not illustrated) for operating the indoor unit 3 or a mobile terminal of a user of the air conditioner 1, and the received estimated value of the remaining refrigerant amount is displayed on a display unit of each of the remote controller and the mobile terminal that have received the estimated value of the remaining refrigerant amount.

[0068] Meanwhile, if the estimation timing has not come at Step S31 (Step S31: No), the control unit 45 returns the process to Step S31. Further, if the average value of the remaining refrigerant amounts calculated at Step S37 is not smaller than the predetermined value (Step S37: No), the control unit 45 returns the process to Step S31.

Effects of first embodiment

[0069] In the air conditioner 1 of the first embodiment, the refrigerant circuit 6 estimates the remaining refrigerant amount in the refrigerant circuit 6 by using the first operating state quantity that indicates an operating state at the time of air conditioning operation while the first stability condition is met and each of the estimation models for cooling operation and heating operation. With use of the first operating state quantity for estimation of the remaining refrigerant amount, it is possible to accurately estimate the remaining refrigerant amount because the first operating state quantity is also used to generate each of the estimation models. Further, if the first stability condition is not met, that is, if it is difficult to achieve a state in which the refrigerant circuit 6 is stable, the refrigerant circuit 6 estimates the remaining refrigerant amount in the refrigerant circuit 6 by using the second operating state quantity that indicates an operating state at the time of air conditioning operation while the second stability condition is met and each of the estimation models for cooling operation and heating operation. With use of the second operating state quantity for estimation of the remaining refrigerant amount, although accuracy of each estimation is reduced as compared to a case in which the first operating state quantity is used, it is possible to ensure certain estimation accuracy of the remaining refrigerant amount by obtaining an average of estimation results and adopting the average value as the estimated value of the remaining refrigerant amounts because a large amount of the second operating state quantity can be obtained as compared to the first operating state quantity.

[0070] If the number of detections of the first operating state quantity in the predetermined period is equal to or larger than the predetermined value, the control unit 45 estimates the remaining refrigerant amount by using the first operating state quantity and the estimation models. If the number of detections of the first operating state quantity in the predetermined period is smaller than the predetermined value, the remaining refrigerant amount is estimated by using the second operating state quantity and the estimation model. As a result, when the remaining refrigerant amount is estimated, it is possible to properly use the first operating state quantity or the second operating state quantity.

[0071] If the control unit 45 estimates the remaining refrigerant amount by using the second operating state quantity and the estimation model at each predetermined timing, the control unit 45 outputs an average value of the remaining refrigerant amounts that are estimated at predetermined timings in the predetermined period, as the remaining refrigerant amount in the predetermined period. As a result, it is possible to estimate the remaining refrigerant amount with high accuracy.

[0072] Meanwhile, in the first embodiment, it is assumed that the first stable condition is met when the certain state, in which the variation of the rotation speed of the compressor 11 falls within the first predetermined range and the absolute value of the difference between the refrigerant discharge temperature and the target discharge temperature of the compressor 11 is equal to or smaller than a predetermined value, continues for the first predetermined period or more. However, it may be possible to assume that the first stable condition is met only when a certain state, in which the variation of the rotation speed of the compressor 11 falls within the first predetermined range, continues for the first predetermined period or more, and an appropriate change is applicable.

[0073] In the first embodiment, it is assumed that the second stable condition is met when the certain state, in which the variation of the rotation speed of the compressor 11 falls within the second predetermined range that exceeds the first predetermined range, continues for the second predetermined period, which exceeds the first predetermined period, or more. However, it may be possible to assume that the second stable condition is met when a certain state, in which the variation of the rotation speed of the compressor 11 falls within the second predetermined range, continues for the first predetermined period or more, even if the certain state does not continue for the second predetermined period or more, and an appropriate change is applicable.

[0074] In the first embodiment, the case has been described in which the remaining refrigerant amount is estimated at each predetermined timing, but estimation need not always be performed regularly, and an appropriate change is applicable.

[0075] In the first embodiment, the case has been described in which each of the operating state quantities is obtained by test drive of the air conditioner 1 at the design stage of the air conditioner 1, and the estimation model that is obtained by causing a terminal, such as a server, with a learning function to perform learning of the test result is stored in the control circuit 18 in advance. Alternatively, it may be possible to acquire each of the operating state quantities by a simulation, and store an estimation model that is obtained by performing learning on an acquired result in advance. Furthermore, it may be possible to provide a server 120 that is connected to the air conditioner 1 by a communication network 110, and the server 120 may generate the first regression equation and the second regression equation and transmit the first regression equation and the second regression equation to the air conditioner 1. This embodiment will be described below.

Second Embodiment

Configuration of air conditioning system

[0076] FIG. 8 is an explanatory diagram illustrating an air conditioning system 100 of a second embodiment. Meanwhile, the same components as those of the air conditioner 1 of the first embodiment are denoted by the same reference symbols, and explanation of the same configurations and the same operation will be omitted. The air conditioning system 100 illustrated in FIG. 8 includes the air conditioner 1 described in the first embodiment, the communication network 110, and the server 120, and the air conditioner 1 is communicably connected to the server 120 via the communication network 110.

[0077] The server 120 includes a generation unit 121 and a transmission unit 122. The generation unit 121 generates an estimation model by a multiple regression analysis method using the operating state quantity that is related to estimation of the remaining refrigerant amount of a refrigerant that is stored in the refrigerant circuit 6. Meanwhile, the estimation model includes, for example, the cooling estimation model 62A and the heating estimation model 62B that are described in the first embodiment. The transmission unit 122 transmits each of the estimation models that are generated by the generation unit 121 to the air conditioner 1 via the communication network 110. The control circuit 18 of the air conditioner 1 calculates the remaining refrigerant amount in the refrigerant circuit 6 in the air conditioner 1 by using each of the received estimation models.

[0078] The generation unit 121 in the server 120 regularly collects operating state quantities at the time of cooling operation from a standard device (installed in a test room of a manufacturing company or the like) of the air conditioner 1 capable of measuring the remaining refrigerant amount in the refrigerant circuit 6, and generates or updates the cooling estimation model 62A by using a comparison result between the remaining refrigerant amount that is estimated by each of the estimation models and the measured remaining refrigerant amount and by using the collected operating state quantities. Further, the transmission unit 122 in the server 120 regularly transmits the generated or updated cooling estimation model 62A to the air conditioner 1. Meanwhile, as in the first embodiment, it may be possible to obtain, by a simulation, the operating state quantity that is used to generate each of the estimation models, and cause the generation unit 121 to generate each of the estimation models by using the operating state quantity that is obtained by the simulation.

[0079] The generation unit 121 in the server 120 regularly collects operating state quantities at the time of heating operation from the standard device of the air conditioner 1 as described above, and generates the heating estimation model 62B by using a comparison result between the remaining refrigerant amount that is estimated by the estimation model and the measured remaining refrigerant amount and by using the collected operating state quantities. Further, the transmission unit 122 in the server 120 regularly transmits the generated heating estimation model 62B to the air conditioner 1. Meanwhile, as in the first embodiment, it may be possible to obtain, by a simulation, the operating state quantity that is used to generate each of the estimation models, and cause the generation unit 121 to generate each of the estimation models by using the operating state quantity that is obtained by the simulation.

Effects of second embodiment

[0080] The server 120 of the second embodiment generates the estimation model for estimating the remaining refrigerant amount by using the multiple regression analysis method using the operating state quantity related to estimation of the remaining refrigerant amount in the refrigerant circuit 6, and transmits the generated estimation model to the air conditioner 1. The air conditioner 1 estimates the remaining refrigerant amount by using the estimation model that is received from the server 120 and the current operating state quantity. As a result, even for the home-use air conditioner 1, it is possible to estimate the remaining refrigerant amount at a current time by using highly accurate estimation model.

[0081] Furthermore, in the present embodiment, the case has been described in which the remaining refrigerant amount in the refrigerant circuit 6 is estimated. However, the present invention is not limited to this example, and in particular, it may be possible to estimate a refrigerant shortage rate that is a ratio of the amount of the refrigerant that has leaked to the outside from the refrigerant circuit 6 to a storage amount (initial value) that is obtained when the refrigerant circuit 6 is filled with the refrigerant. Moreover, it may be possible to multiply the estimated refrigerant shortage rate by the initial value, and provide the amount of the refrigerant that has leaked from the refrigerant circuit 6 to the outside. Furthermore, it may be possible to generate an estimation model that estimates an absolute amount of the refrigerant that has leaked from the refrigerant circuit 6 to the outside or an absolute amount of the refrigerant that remains in the refrigerant circuit 6, and provide an estimation result obtained by the estimation model. When the estimation model that estimates the absolute amount of the refrigerant that has leaked from the refrigerant circuit 6 to the outside or the absolute amount of the refrigerant that remains in the refrigerant circuit 6 is to be generated, it is sufficient to take into account capacities of the outdoor heat exchanger 13 and the indoor heat exchanger 51 or a capacity of the liquid pipe 4, in addition to each operating state quantity as described above.

[0082] Moreover, if it is assumed that 100% indicates that a defined amount of refrigerant is stored, the refrigerant shortage rate is a ratio of a decrease amount with respect to the defined amount. Alternatively, it may be possible to estimate the refrigerant shortage rate immediately after the defined amount of refrigerant is stored in the refrigerant circuit 6, and adopt an estimation result as 100%. For example, if the refrigerant shortage rate that is estimated immediately after the defined amount of refrigerant is stored in the refrigerant circuit 6 is 90%, that is, if it is estimated that the amount of the refrigerant stored in the refrigerant circuit 6 is smaller than the defined amount by 10%, it may be possible to adopt the refrigerant amount that is smaller than the defined amount by 10% as 100%. In this manner, by adjusting the refrigerant amount that is adopted as 100% to the estimation result, it is possible to more accurately estimate ae subsequent refrigerant shortage rate.

Modification

[0083] In the present embodiment, the case has been described in which the control circuit 18 included in the indoor unit 3 controls the entire air conditioner 1, but the control circuit 18 may be provided in the outdoor unit 2 or a cloud side. In the present embodiment, the case has been described in which the estimation model is generated by the server 120, but the estimation model may be calculated by a human being, instead of the server 120, from a simulation result. Furthermore, in the present embodiment, the case has been described in which the control circuit 18 of the indoor unit 3 estimates the refrigerant amount by using the estimation model, but the server 120 that generates the estimation model may estimate the refrigerant amount. Moreover, in the present embodiment, the case has been described in which each of the estimation models is generated by using the multiple regression analysis method, but the estimation models may be generated by using a support vector regression (SVR), a neural network (NN), or the like that is a machine learning method capable of performing a general regression analysis method. In this case, to select a feature value, it is sufficient to use a general method (forward feature selection method, backward feature elimination, or the like) for selecting the feature value such that accuracy of the estimation models is improved, instead of the P value and the correction value R2 that are used in the multiple regression analysis method.

[0084] Moreover, the components of the units illustrated in the drawings are conceptual function, and need not always be physically configured in the manner illustrated in the drawings. In other words, specific forms of distribution and integration of the units are not limited to those illustrated in the drawings, and all or part of the units may be functionally or physically distributed or integrated in arbitrary units depending on various loads or use conditions.

[0085] Further, all or an arbitrary part of the processing functions implemented by the apparatuses may be realized by a central processing unit (CPU) (or a microcomputer, such as a micro processing unit (MPU) or a micro controller unit (MCU)). Furthermore, all or an arbitrary part of the processing functions may be may be implemented by a program that is executed by a CPU (or a microcomputer, such as an MPU or an MCU) or hardware using wired logic.

Reference Signs List

[0086]

1	air conditioner
2	outdoor unit
3	indoor unit
11	compressor
18	control circuit
42	acquisition unit
43	detection unit
44	storage unit
45	control unit
61A	first operating state quantity memory
61B	second operating state quantity memory
62A	cooling estimation model
62B	heating estimation model

Claims

1. An air conditioner that includes a refrigerant circuit that is formed by connecting, by a refrigerant pipe, an indoor unit including an indoor heat exchanger to an outdoor unit including a compressor, an outdoor heat exchanger, and an expansion valve, the refrigerant circuit being filled with a predetermined amount of a refrigerant, the air conditioner comprising:

an acquisition unit that regularly acquires an operating state quantity at a time of air conditioning operation;
a storage unit that stores therein the operating state quantity that is acquired by the acquisition unit;
an estimation model that estimates a refrigerant remaining amount in the refrigerant circuit by using the operating state quantity;
a detection unit that detects, from the storage unit, one of a first operating state quantity and a second operating state quantity, the first operating state quantity being an operating state quantity in a state in which the refrigerant circuit meets a first stability condition, the second operating state quantity being an operating state quantity in a state in which the refrigerant circuit meets a second stability condition that is different from the first stability condition; and
a control unit that estimates the remaining refrigerant amount in the refrigerant circuit by using the estimation model and the operating state quantity that is detected by the detection unit.

2. The air conditioner according to claim 1, wherein the second stability condition is a mild condition as compared to the first stability condition.

3. The air conditioner according to claim 1 or 2, wherein the control unit

estimates the remaining refrigerant amount by using the first operating state quantity and the estimation model if number of detections of the first operating state quantity detected by the detection unit in a predetermined period is equal to or larger than a predetermined value, and
estimates the remaining refrigerant amount by using the second operating state quantity and the estimation model if the number of detections of the first operating state quantity detected by the detection unit in the predetermined period is smaller than the predetermined value.

4. The air conditioner according to claim 1 or 2, wherein the detection unit

adopts, as the first operating state quantity, the operating state quantity that is detected in a state in which the first stability condition is met, the state being a state in which variation of a rotation speed of the compressor falls within a first predetermined range for a first predetermined period or more, and
adopts, as the second operating state quantity, the operating state quantity that is detected in a state in which the second stability condition is met, the state being a state in which the variation of the rotation speed of the compressor falls within a second predetermined range that exceeds the first predetermined range for the first predetermined period or more or for a second predetermined period or more, the second predetermined period exceeding the first predetermined period.

5. The air conditioner according to claim 4, wherein the detection unit adopts, as the first operating state quantity, the operating state quantity that is detected in a state in which the first stability condition is met, the state being a state in which an absolute value of a difference between refrigerant discharge temperature and target discharge temperature of the compressor is equal to or smaller than a predetermined value for the first predetermined period or more, in addition to when the first condition is met.

6. The air conditioner according to claim 1 or 2, wherein the detection unit detects the first operating state quantity and the second operating state quantity.

7. The air conditioner according to claim 1 or 2, wherein if the control unit estimates the remaining refrigerant amount by using the second operating state quantity and the estimation model at each predetermined timing, the control unit outputs, as the remaining refrigerant amount in the predetermined period, an average value of the remaining refrigerant amounts that are estimated at the respective predetermined timings in the predetermined period.

FIG.1

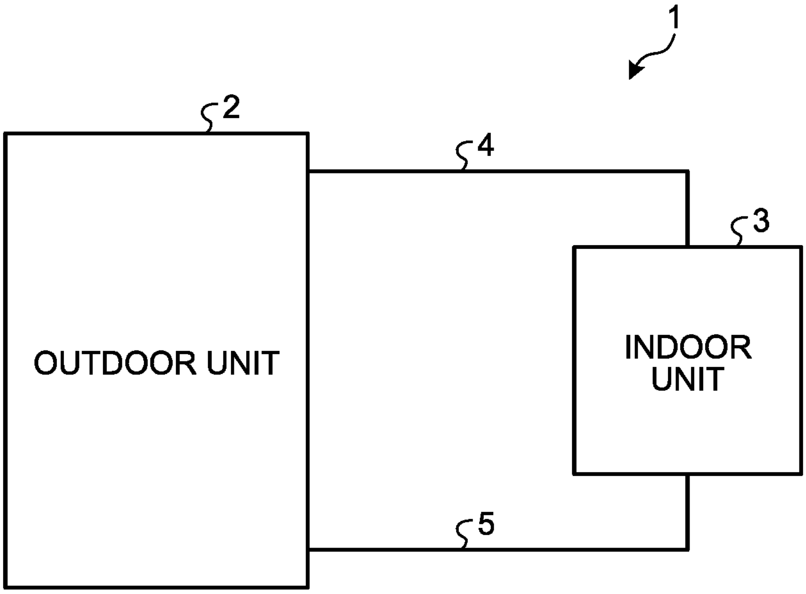


FIG.2

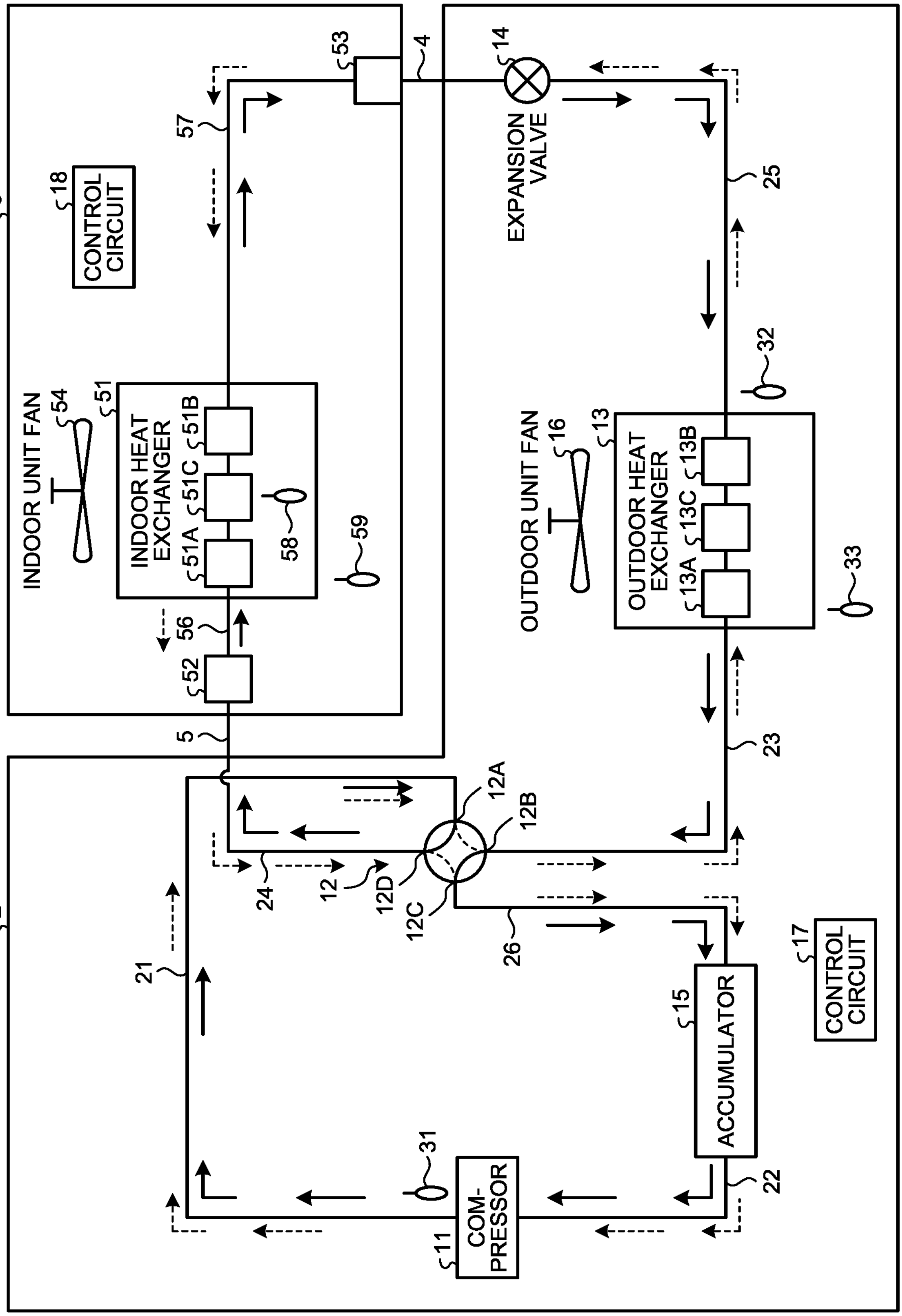

6
3
CONTROL CIRCUIT
18
INDOOR UNIT FAN
54
51
INDOOR HEAT EXCHANGER
51A
51C
51B
58
59
52
56
57
53
4
5
14
EXPANSION VALVE
25
32
OUTDOOR UNIT FAN
16
13
OUTDOOR HEAT EXCHANGER
13A
13C
13B
33
23
2
12A
12B
12
12D
12C
24
21
26
17
CONTROL CIRCUIT
15
ACCUMULATOR
22
31
11
COM-PRESSOR

FIG.3

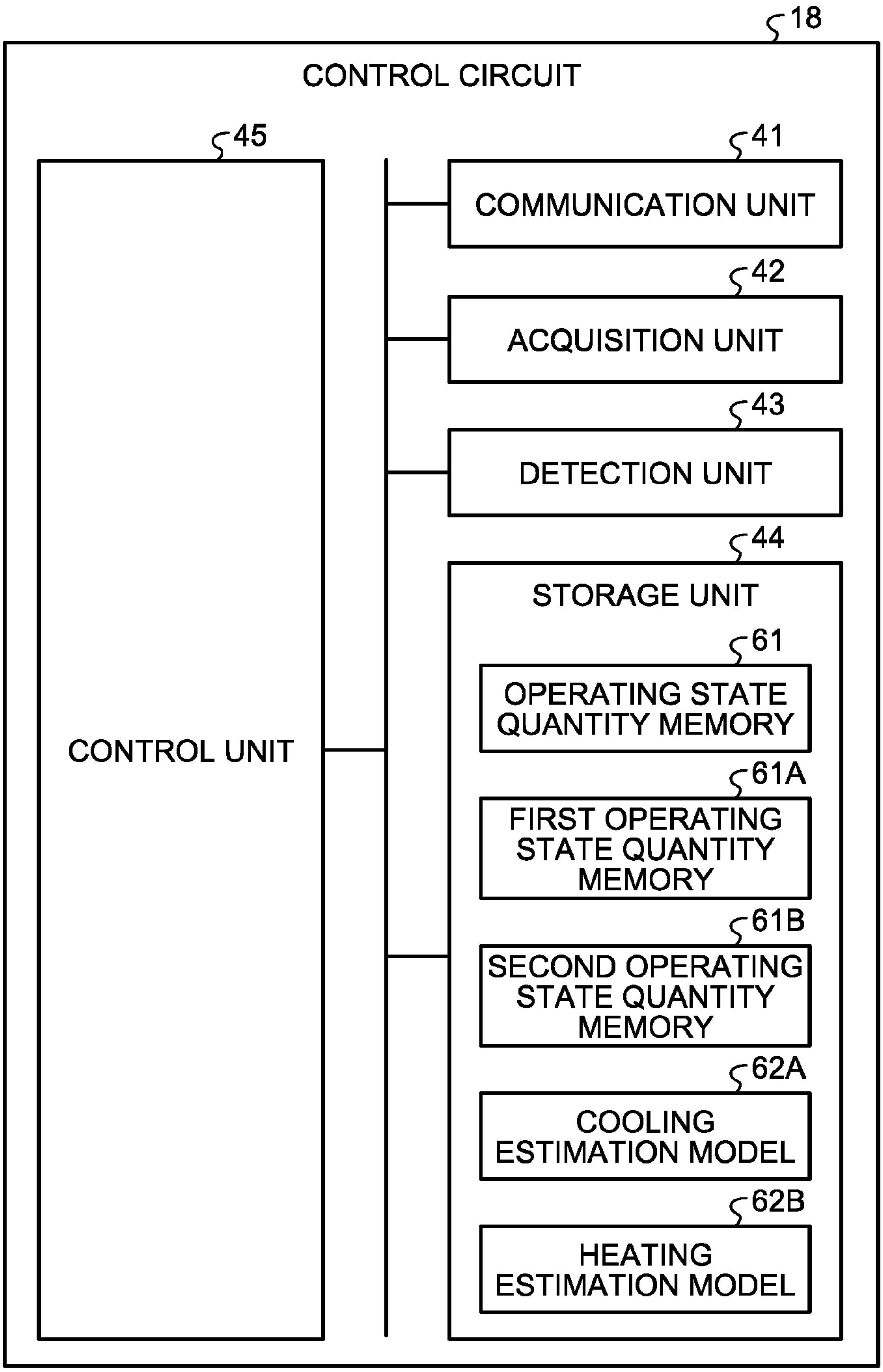

18
CONTROL CIRCUIT
45
CONTROL UNIT
41
COMMUNICATION UNIT
42
ACQUISITION UNIT
43
DETECTION UNIT
44
STORAGE UNIT
61
OPERATING STATE QUANTITY MEMORY
61A
FIRST OPERATING STATE QUANTITY MEMORY
61B
SECOND OPERATING STATE QUANTITY MEMORY
62A
COOLING ESTIMATION MODEL
62B
HEATING ESTIMATION MODEL

FIG.4

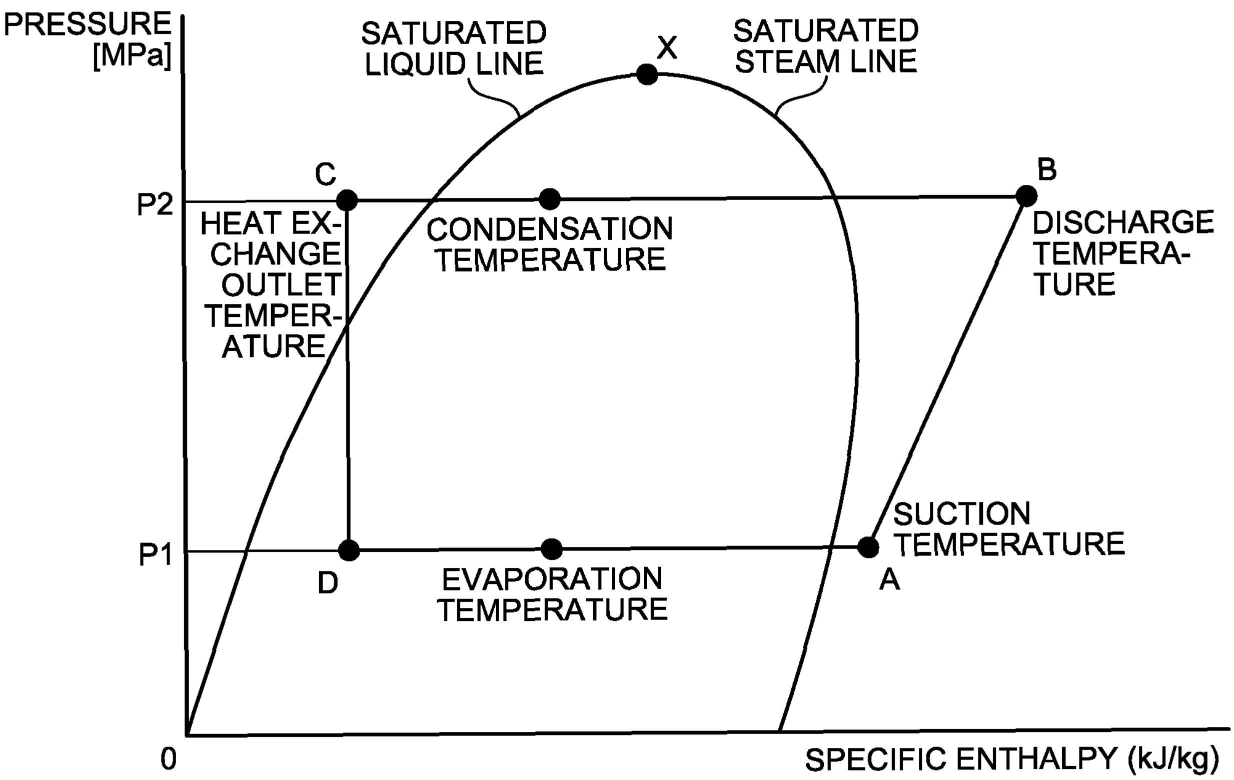

PRESSURE [MPa]
SATURATED LIQUID LINE
X
SATURATED STEAM LINE
C
B
P2
HEAT EX-CHANGE OUTLET TEMPER-ATURE
CONDENSATION TEMPERATURE
DISCHARGE TEMPERA-TURE
SUCTION TEMPERATURE
P1
D
EVAPORATION TEMPERATURE
A
0
SPECIFIC ENTHALPY (kJ/kg)

FIG.5

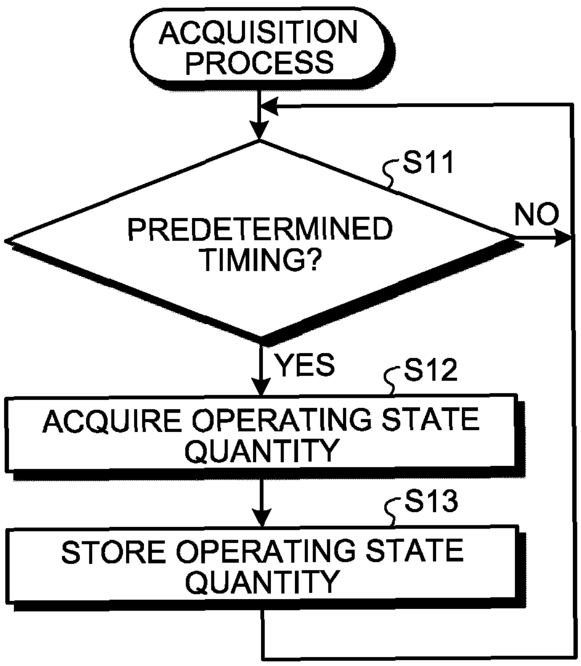

ACQUISITION PROCESS
S11
PREDETERMINED TIMING?
NO
YES
S12
ACQUIRE OPERATING STATE QUANTITY
S13
STORE OPERATING STATE QUANTITY

FIG.6

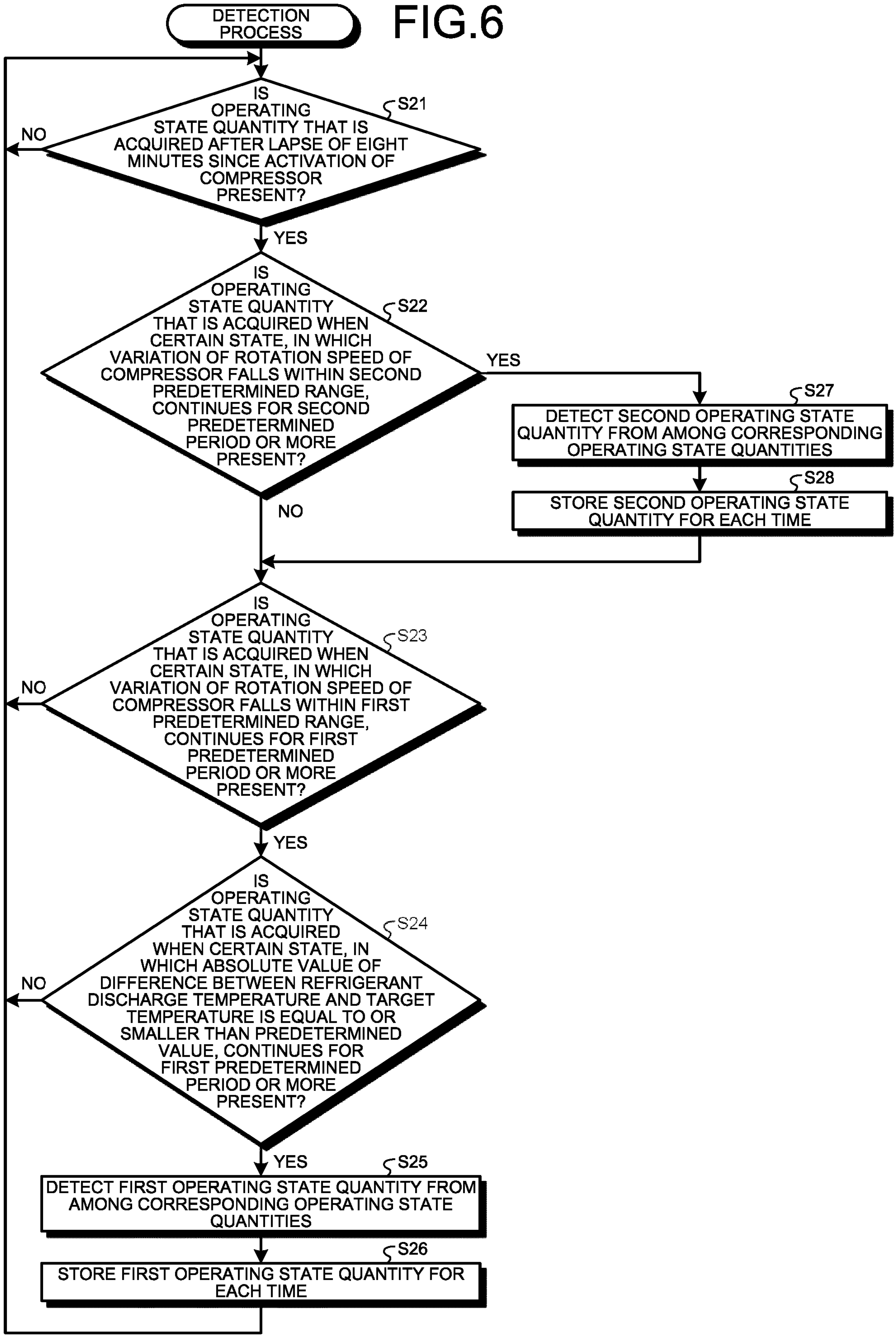

DETECTION PROCESS
IS OPERATING STATE QUANTITY THAT IS ACQUIRED AFTER LAPSE OF EIGHT MINUTES SINCE ACTIVATION OF COMPRESSOR PRESENT?
S21
NO
YES
IS OPERATING STATE QUANTITY THAT IS ACQUIRED WHEN CERTAIN STATE, IN WHICH VARIATION OF ROTATION SPEED OF COMPRESSOR FALLS WITHIN SECOND PREDETERMINED RANGE, CONTINUES FOR SECOND PREDETERMINED PERIOD OR MORE PRESENT?
S22
YES
S27
DETECT SECOND OPERATING STATE QUANTITY FROM AMONG CORRESPONDING OPERATING STATE QUANTITIES
S28
STORE SECOND OPERATING STATE QUANTITY FOR EACH TIME
NO
IS OPERATING STATE QUANTITY THAT IS ACQUIRED WHEN CERTAIN STATE, IN WHICH VARIATION OF ROTATION SPEED OF COMPRESSOR FALLS WITHIN FIRST PREDETERMINED RANGE, CONTINUES FOR FIRST PREDETERMINED PERIOD OR MORE PRESENT?
S23
NO
YES
IS OPERATING STATE QUANTITY THAT IS ACQUIRED WHEN CERTAIN STATE, IN WHICH ABSOLUTE VALUE OF DIFFERENCE BETWEEN REFRIGERANT DISCHARGE TEMPERATURE AND TARGET TEMPERATURE IS EQUAL TO OR SMALLER THAN PREDETERMINED VALUE, CONTINUES FOR FIRST PREDETERMINED PERIOD OR MORE PRESENT?
S24
NO
YES
S25
DETECT FIRST OPERATING STATE QUANTITY FROM AMONG CORRESPONDING OPERATING STATE QUANTITIES
S26
STORE FIRST OPERATING STATE QUANTITY FOR EACH TIME

FIG.7

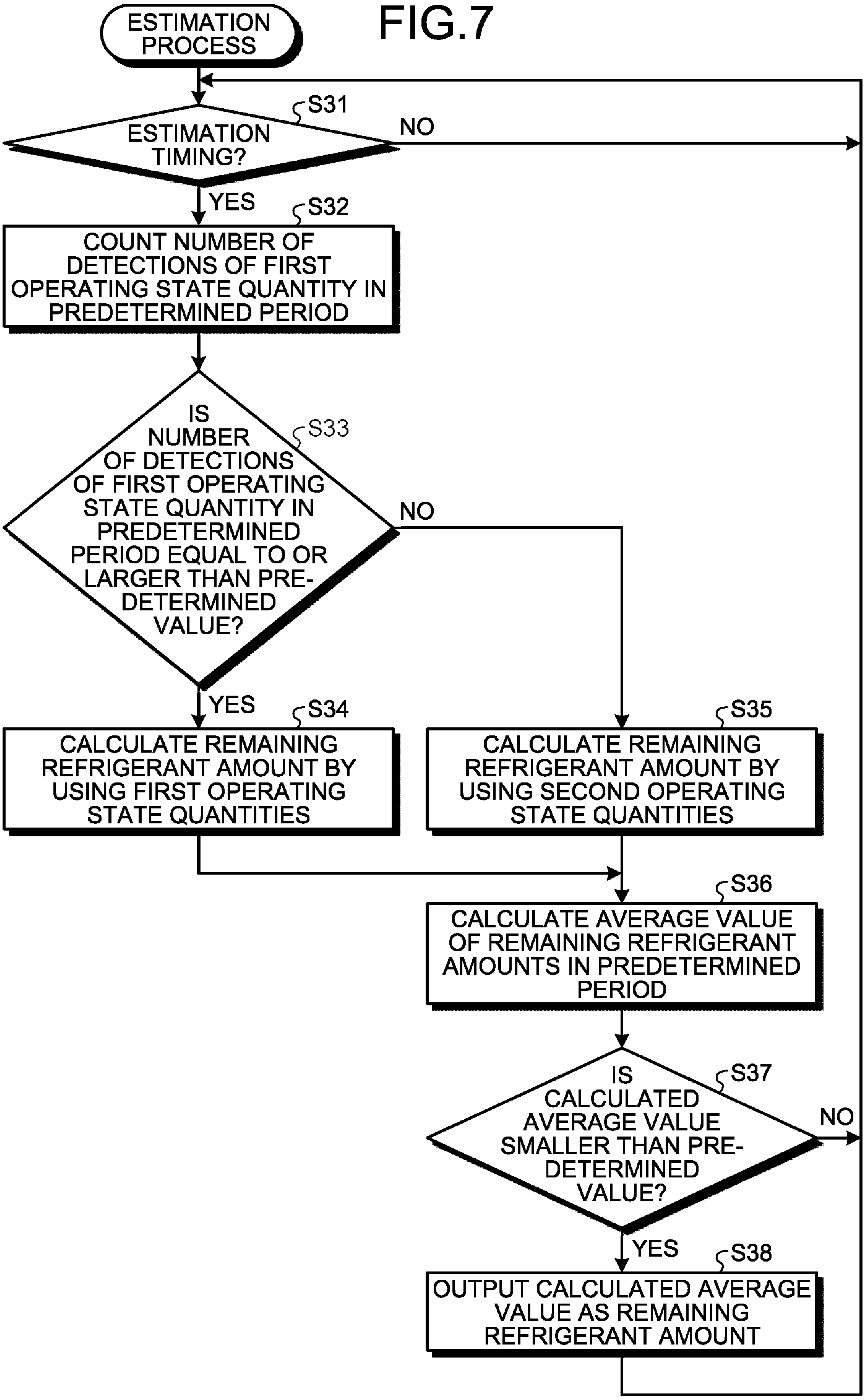
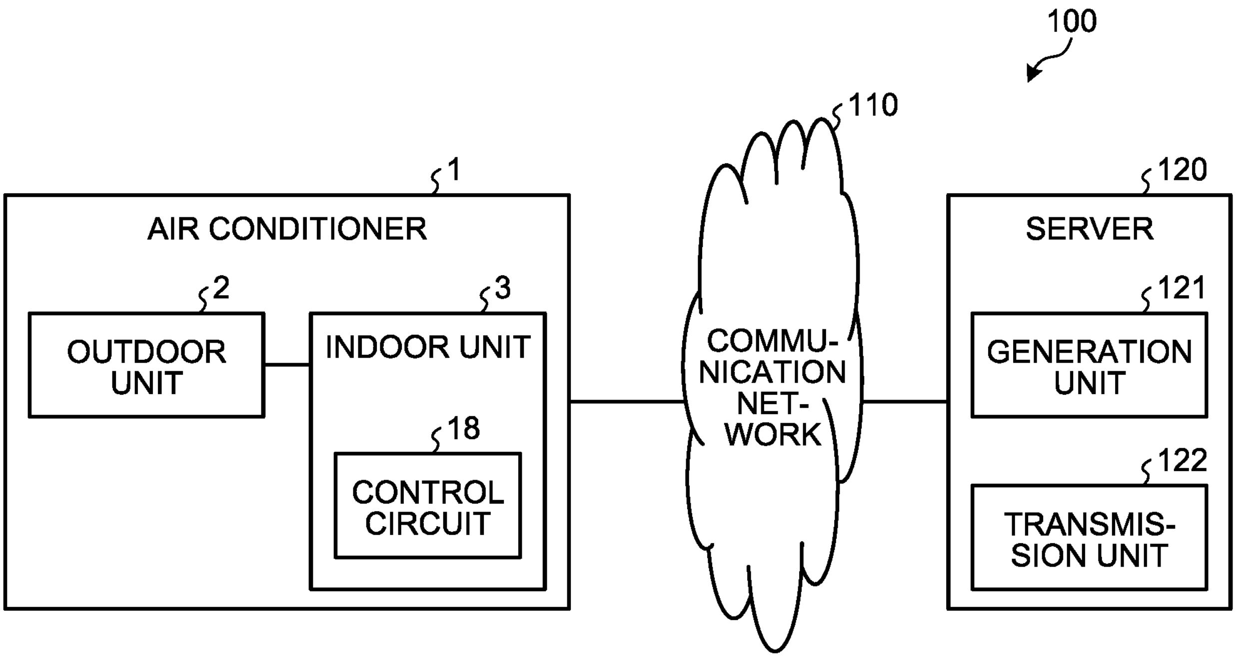

ESTIMATION PROCESS
S31
ESTIMATION TIMING?
NO
YES
S32
COUNT NUMBER OF DETECTIONS OF FIRST OPERATING STATE QUANTITY IN PREDETERMINED PERIOD
S33
IS NUMBER OF DETECTIONS OF FIRST OPERATING STATE QUANTITY IN PREDETERMINED PERIOD EQUAL TO OR LARGER THAN PRE-DETERMINED VALUE?
NO
YES
S34
CALCULATE REMAINING REFRIGERANT AMOUNT BY USING FIRST OPERATING STATE QUANTITIES
S35
CALCULATE REMAINING REFRIGERANT AMOUNT BY USING SECOND OPERATING STATE QUANTITIES
S36
CALCULATE AVERAGE VALUE OF REMAINING REFRIGERANT AMOUNTS IN PREDETERMINED PERIOD
S37
IS CALCULATED AVERAGE VALUE SMALLER THAN PRE-DETERMINED VALUE?
NO
YES
S38
OUTPUT CALCULATED AVERAGE VALUE AS REMAINING REFRIGERANT AMOUNT

FIG.8


100
110
1
AIR CONDITIONER
2
OUTDOOR UNIT
3
INDOOR UNIT
18
CONTROL CIRCUIT
COMMU-NICATION NET-WORK
120
SERVER
121
GENERATION UNIT
122
TRANSMIS-SION UNIT

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/038644

A. CLASSIFICATION OF SUBJECT MATTER

F24F 11/49(2018.01)i; ***F25B 49/02***(2006.01)i
FI: F25B49/02 520K; F25B49/02 520Z; F24F11/49

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; F24F11/00-11/89

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-127950 A (DENSO CORP) 11 June 2009 (2009-06-11) paragraphs [0036]-[0091], [0107]-[0136], [0152], [0154], fig. 1-4, 8-12	1-3, 6
Y	paragraphs [0036]-[0091], [0107]-[0136], [0152], [0154], fig. 1-4, 8-12	4-5, 7
Y	JP 2012-229893 A (MITSUBISHI ELECTRIC CORP) 22 November 2012 (2012-11-22) paragraphs [0106]-[0109], fig. 1, 8	4-5
Y	JP 2000-130897 A (HITACHI LTD) 12 May 2000 (2000-05-12) paragraphs [0033]-[0035], fig. 1, 5	5
Y	JP 2012-132601 A (SAMSUNG YOKOHAMA RESEARCH INSTITUTE CO LTD) 12 July 2012 (2012-07-12) paragraph [0016], [0018]	7

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

* Special categories of cited documents:
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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
15 November 2021	**30 November 2021**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/038644

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2009-127950 A	11 June 2009	(Family: none)	
JP 2012-229893 A	22 November 2012	(Family: none)	
JP 2000-130897 A	12 May 2000	(Family: none)	
JP 2012-132601 A	12 July 2012	(Family: none)	

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Patent documents cited in the description

- JP 2006023072 A **[0003]**