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(54) REFRIGERANT CYCLE SYSTEM

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(52) **U.S. Cl.** **62/225**; 62/500; 62/505; 417/410.1; 62/428

(57) **ABSTRACT**

In a refrigerant cycle system, a compression mechanism of an electric compressor sucks and compresses refrigerant, and an electric motor that drives the compression mechanism is cooled by the refrigerant. A variable throttle mechanism decompresses the refrigerant discharged from the electric compressor. A motor temperature detector detects a temperature of the electric motor. A motor protection determiner determines whether the temperature of the electric motor detected by the motor temperature detector is equal to or higher than a criterion value. A motor protection controller controls the variable throttle mechanism so that an opening degree of the variable throttle mechanism does not decrease when the motor protection determiner determines that the temperature of the electric motor is equal to or higher than the criterion value.

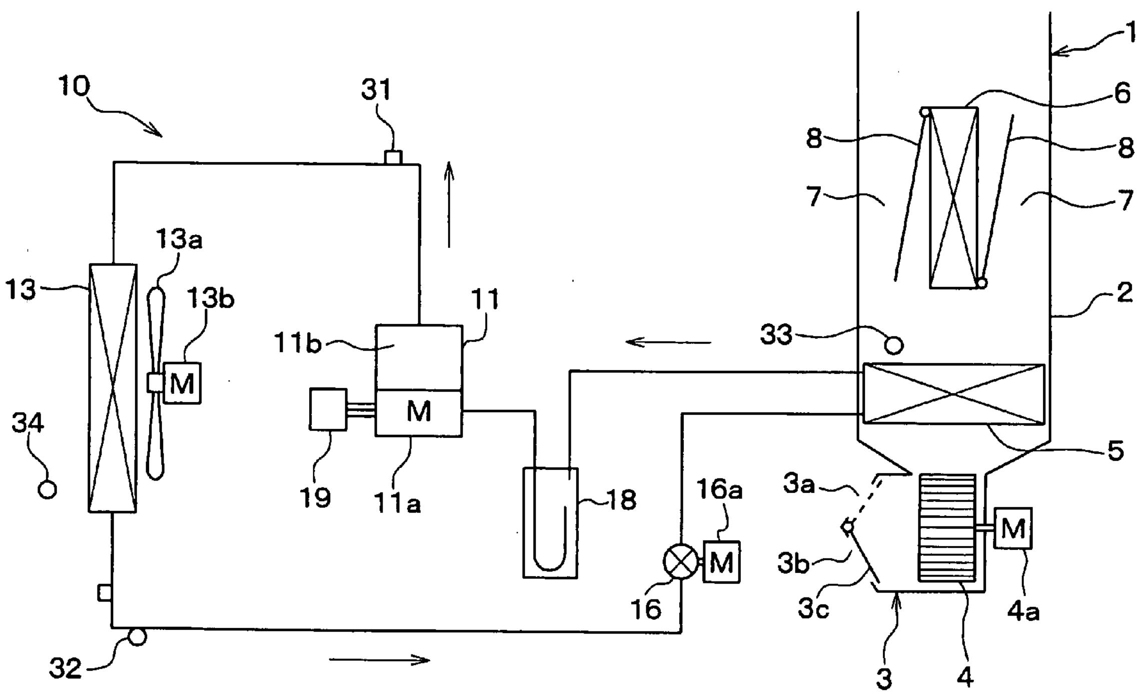
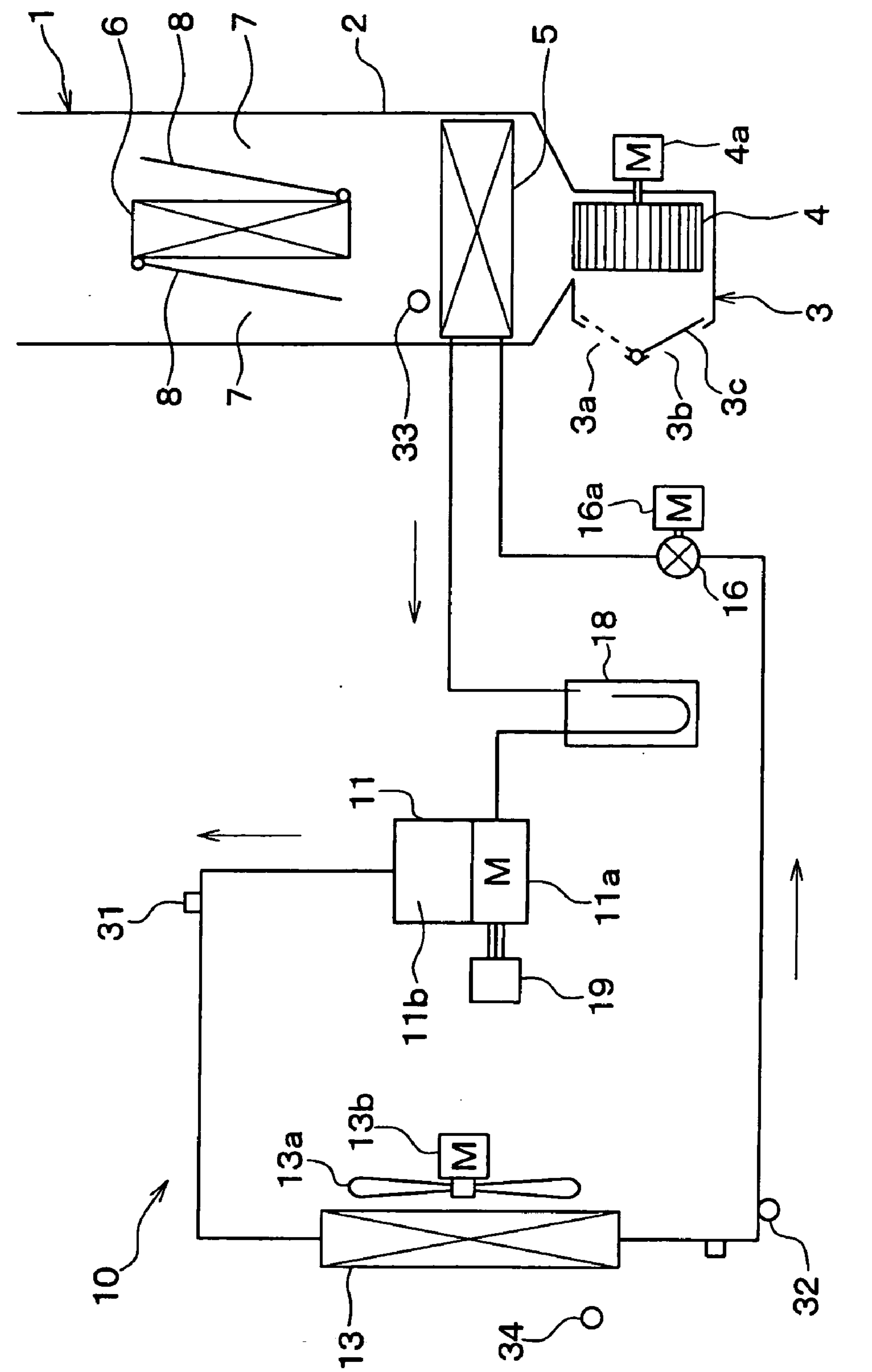


FIG. 1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3a
3b
3c
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4a
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6
7
8
10
11
11a
11b
13
13a
13b
16
16a
18
19
31
32
33
34
M

FIG. 2

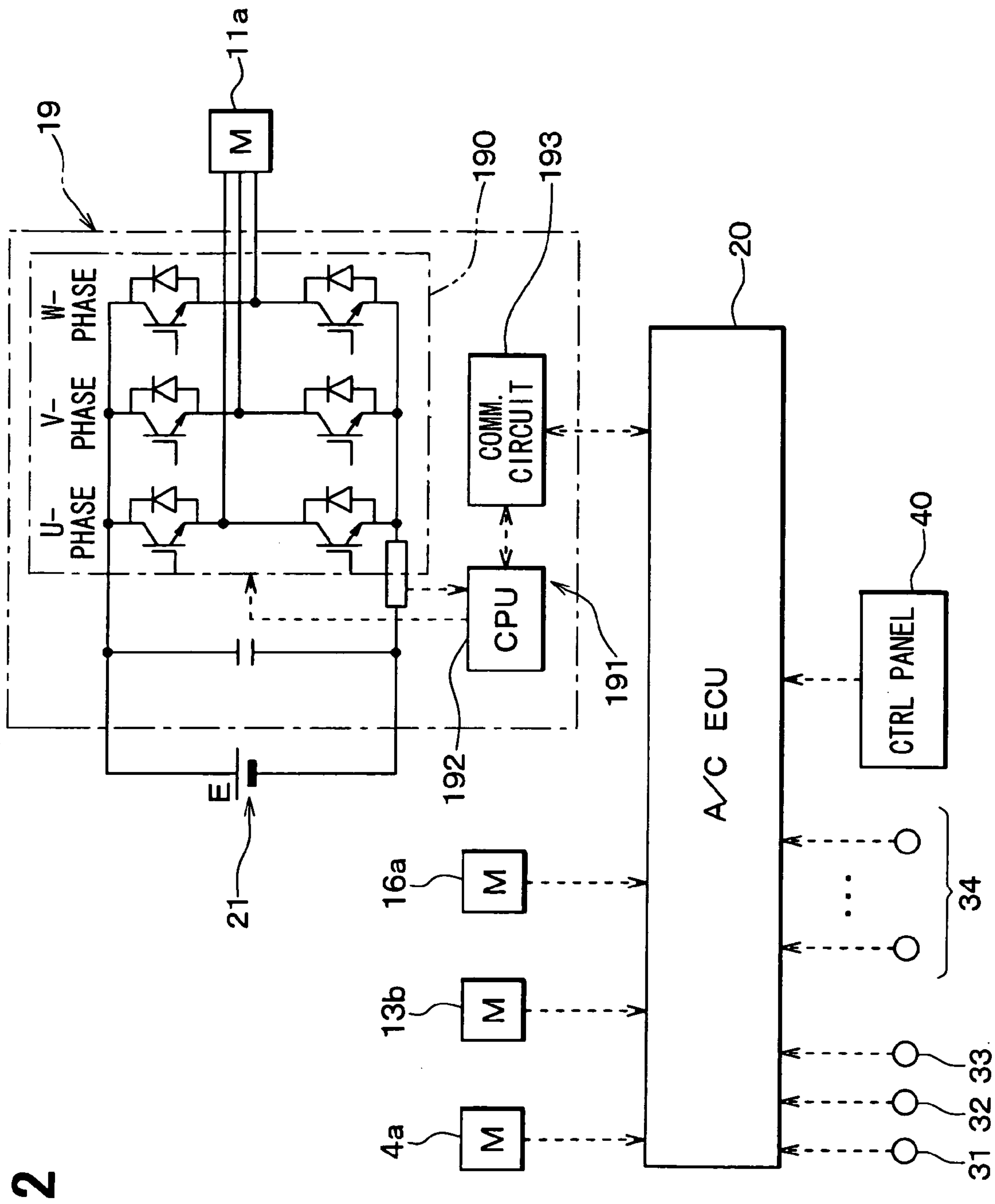
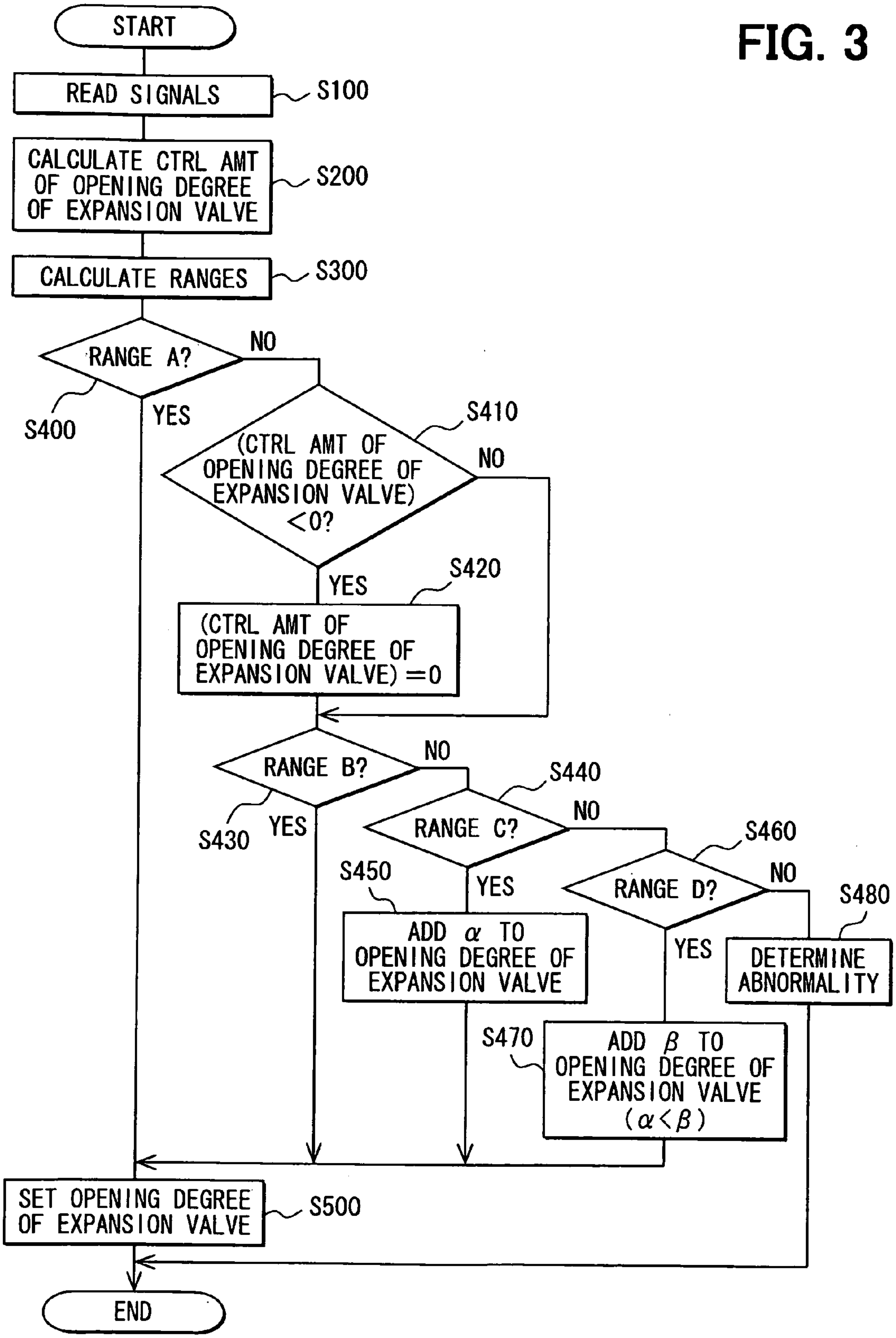

19
11a
M
190
193
U-PHASE
V-PHASE
W-PHASE
COMM. CIRCUIT
CPU
191
192
E
21
20
A/C ECU
40
CTRL PANEL
16a
13b
4a
M
M
M
34
31
32
33

FIG. 3



START
READ SIGNALS
S100
CALCULATE CTRL AMT OF OPENING DEGREE OF EXPANSION VALVE
S200
CALCULATE RANGES
S300
RANGE A?
S400
YES
NO
(CTRL AMT OF OPENING DEGREE OF EXPANSION VALVE) <0?
S410
NO
YES
(CTRL AMT OF OPENING DEGREE OF EXPANSION VALVE) =0
S420
RANGE B?
S430
YES
NO
RANGE C?
S440
YES
NO
RANGE D?
S460
YES
NO
ADD α TO OPENING DEGREE OF EXPANSION VALVE
S450
ADD β TO OPENING DEGREE OF EXPANSION VALVE (α<β)
S470
DETERMINE ABNORMALITY
S480
SET OPENING DEGREE OF EXPANSION VALVE
S500
END

FIG. 4

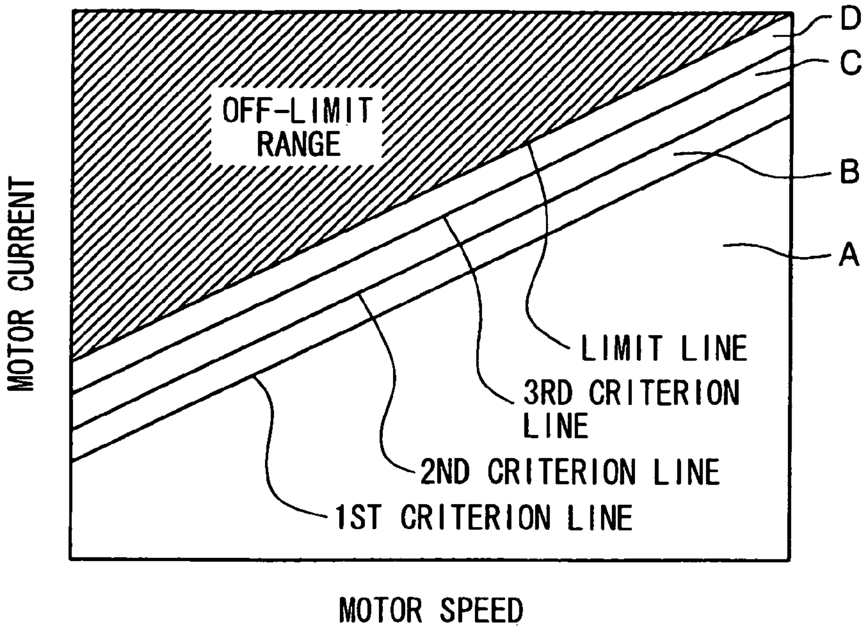

OFF-LIMIT RANGE
D
C
B
A
LIMIT LINE
3RD CRITERION LINE
2ND CRITERION LINE
1ST CRITERION LINE
MOTOR CURRENT
MOTOR SPEED

FIG. 6

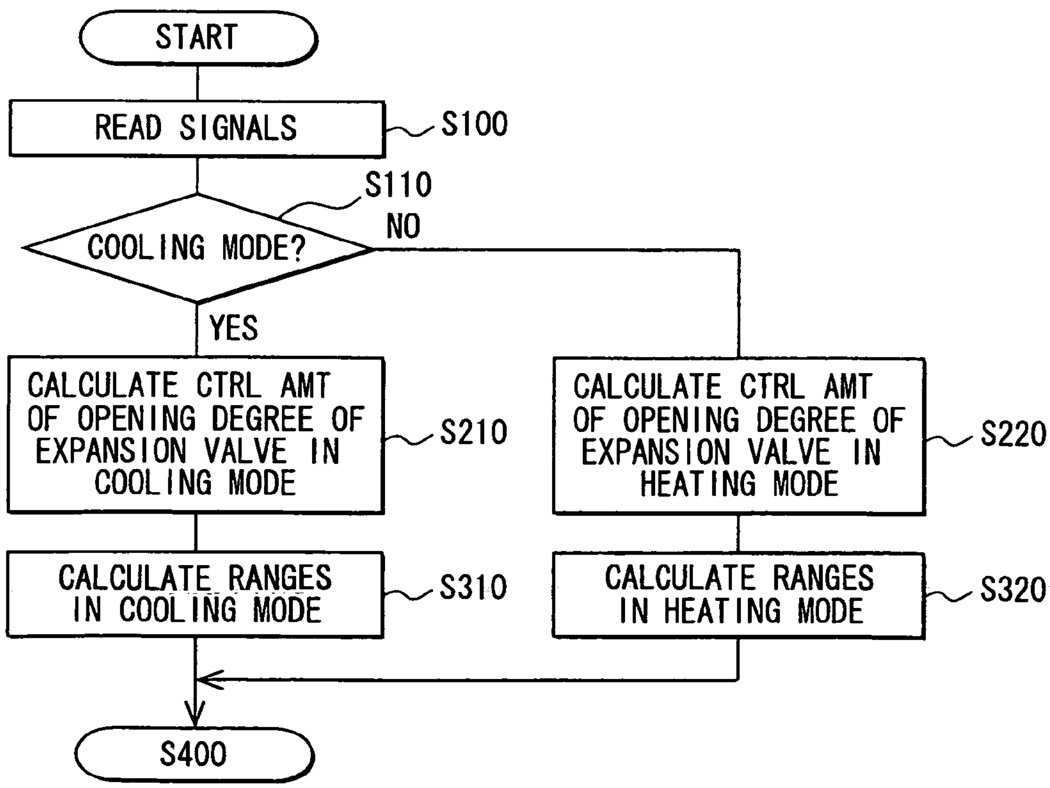

START
READ SIGNALS
S100
S110
COOLING MODE?
NO
YES
CALCULATE CTRL AMT OF OPENING DEGREE OF EXPANSION VALVE IN COOLING MODE
S210
CALCULATE CTRL AMT OF OPENING DEGREE OF EXPANSION VALVE IN HEATING MODE
S220
CALCULATE RANGES IN COOLING MODE
S310
CALCULATE RANGES IN HEATING MODE
S320
S400

FIG. 5

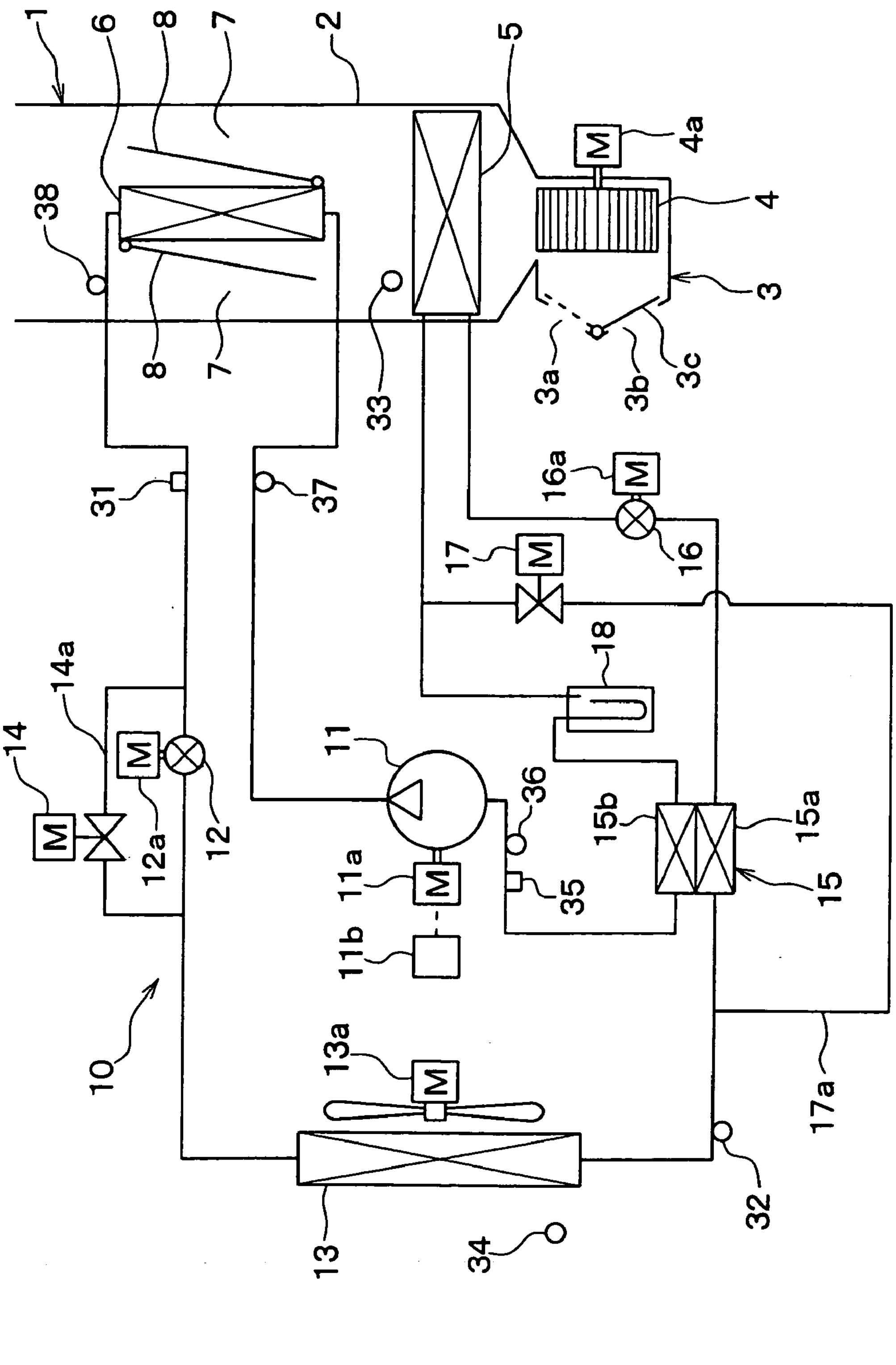

1
2
3
3a
3b
3c
4
4a
5
6
7
8
10
11
11a
11b
12
12a
13
13a
14
14a
15
15a
15b
16
16a
17
17a
18
31
32
33
34
35
36
37
38
M

FIG. 7A

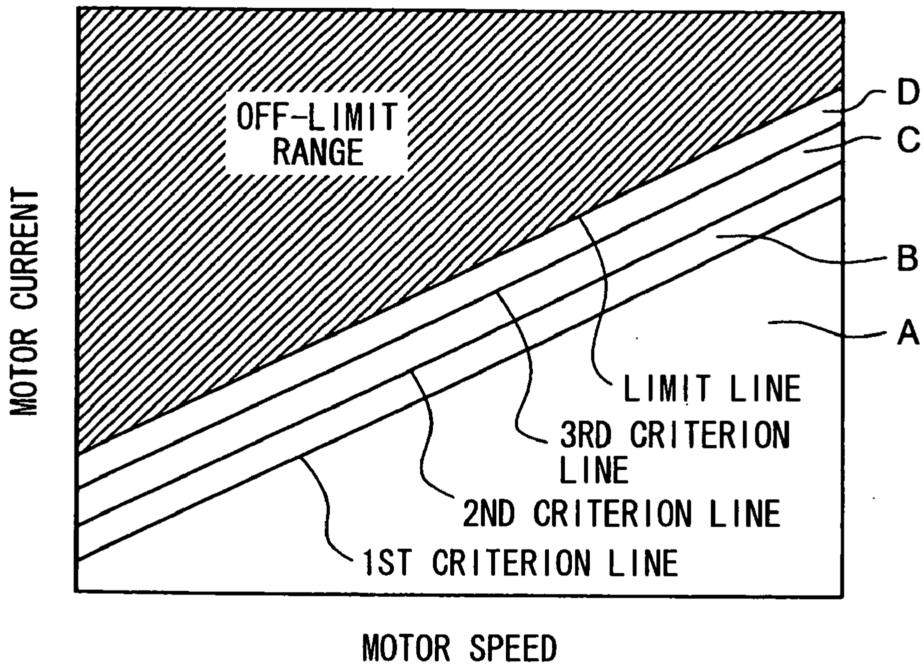
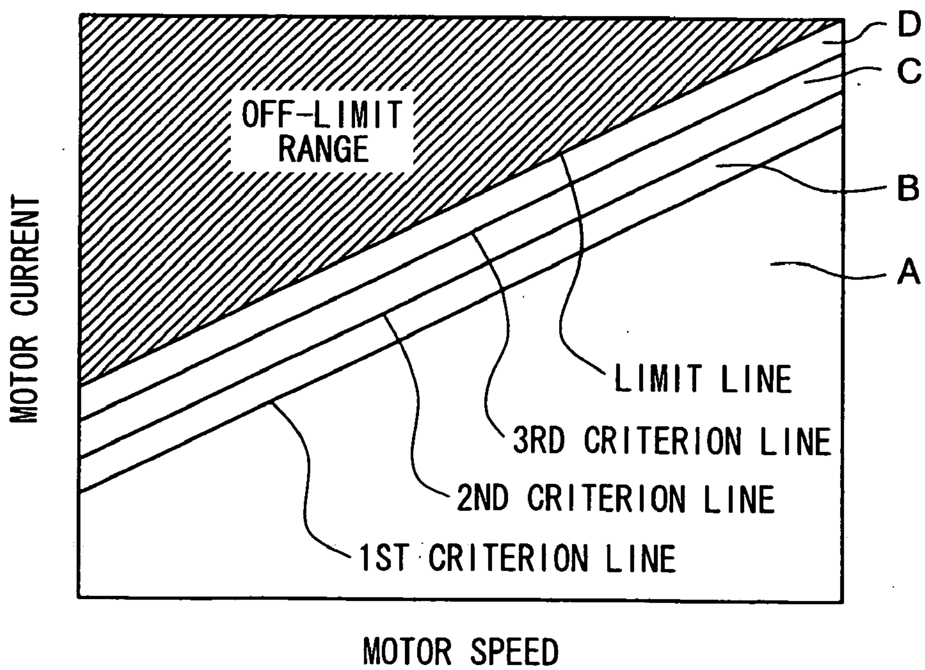

OFF-LIMIT RANGE
D
C
B
A
LIMIT LINE
3RD CRITERION LINE
2ND CRITERION LINE
1ST CRITERION LINE
MOTOR CURRENT
MOTOR SPEED

FIG. 7B


OFF-LIMIT RANGE
D
C
B
A
LIMIT LINE
3RD CRITERION LINE
2ND CRITERION LINE
1ST CRITERION LINE
MOTOR CURRENT
MOTOR SPEED

REFRIGERANT CYCLE SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based on and incorporates herein by reference Japanese Patent Application No. 2008-082749 filed on Mar. 27, 2008.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a refrigerant cycle system having an electric compressor.

[0004] 2. Description of Related Art

[0005] Conventionally, in an electric compressor in which a compression mechanism and an electric motor for driving the compression mechanism are integrated, a temperature protection control is performed as disclosed in JP2006-291878A and JP2005-248730A, for example. In order to avoid excessive temperature rise of the electric motor, the temperature protection control is performed when the temperature of an inverter, the electric motor, etc., excessively rises due to heavy load condition of the electric compressor.

[0006] In JP2006-291878A, the temperature of the electric motor is evaluated on the basis of the motor speed of the electric compressor, the input current of the inverter, etc. The excessive temperature rise of the electric motor is avoided by stopping the electric compressor when the evaluated temperature of the electric motor exceeds a predetermined value. In JP2005-248730A, the electric compressor has a construction in which refrigerant sucked into the electric compressor cools an inverter that includes a driving circuit for the electric motor. In the electric compressor, the motor speed of the electric motor is raised or the electric compressor is stopped to inhibit the temperature rise of the inverter, which occurs when the rotational speed of the electric converter is small although the torque that should be generated by the electric motor is large.

[0007] In JP2006-291878A, the electric compressor is stopped in order to avoid the temperature rise of the electric motor. However, if a refrigerant cycle system having the electric compressor is applied to a vehicular air conditioning system, there is a problem that the air conditioning feeling etc. in a passenger compartment becomes worse significantly.

[0008] The construction of the electric compressor disclosed in JP2005-248730A is for protecting an inverter device from excessive temperature rise. However, when the temperature of the inverter rises, a current value inputted into the electric motor is also large. Therefore, heat generation in the electric motor is large, and the electric motor is in a high temperature state. In this situation, a temperature protection control of the electric motor is performed by stopping the electric compressor as in JP2006-291878A, and the same problem as in JP2006-291878A occurs.

SUMMARY OF THE INVENTION

[0009] The present invention is made in view of the abovementioned problem. Thus, it is an objective of the present invention to provide a refrigerant cycle system that can perform temperature protection control for avoiding excessive temperature rise of an electric motor of an electric compressor without stopping the electric compressor more than necessary.

[0010] To achieve the objective of the present invention, there is provided a refrigerant cycle system that has an electric compressor, a variable throttle mechanism, a motor temperature detector, a motor protection determiner and a motor protection controller. The electric compressor includes a compression mechanism, which sucks and compresses refrigerant, and an electric motor, which drives the compression mechanism and is cooled by the refrigerant at a suction side of the compression mechanism. The variable throttle mechanism decompresses the refrigerant discharged from the electric compressor. The motor temperature detector detects a temperature of the electric motor. The motor protection determiner determines whether the temperature of the electric motor detected by the motor temperature detector is equal to or higher than a criterion value. The motor protection controller controls the variable throttle mechanism so that an opening degree of the variable throttle mechanism does not decrease when the motor protection determiner determines that the temperature of the electric motor is equal to or higher than the criterion value.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention, together with additional objectives, features and advantages thereof, will be best understood from the following description, the appended claims and the accompanying drawings in which:

[0012] FIG. **1** is a schematic diagram showing the configuration of a refrigerant cycle system according to a first embodiment of the present invention;

[0013] FIG. **2** is a block diagram showing an electric control portion of the refrigerant cycle system according to the first embodiment;

[0014] FIG. **3** is a flowchart showing a process for setting an opening degree of an electric expansion valve of the refrigerant cycle system according to the first embodiment;

[0015] FIG. **4** is a control characteristic diagram showing a motor temperature associated with a motor current and a motor speed of an electric motor of an electric compressor of the refrigerant cycle system according to the first embodiment;

[0016] FIG. **5** is a schematic diagram showing the configuration of a refrigerant cycle system according to a second embodiment of the present invention;

[0017] FIG. **6** is a flowchart showing a principal part of a process for setting opening degree of an electric expansion valve of the refrigerant cycle system according to the second embodiment; and

[0018] FIGS. **7**A, **7**B are control characteristic diagrams showing a motor temperature associated with a motor current and a motor speed of an electric motor of an electric compressor of the refrigerant cycle system according to the second embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

First Embodiment

[0019] A first embodiment of the present invention will be described hereafter, referring to FIGS. **1**-**4**. FIG. **1** is a schematic diagram showing an entire construction of a refrigerant cycle system according to the first embodiment, which is applied to a vehicular air conditioning system. As shown in FIG. **1**, the vehicular air conditioning system according to the first embodiment has an interior air conditioning unit **1** that is installed inside an instrument panel, which is located at a front-most part of a passenger compartment of a vehicle to form an instrument board etc.

[0020] The interior air conditioning unit **1** has a case member **2** that is made of resin. The case member **2** forms an outer shell of the interior air conditioning unit **1**, and houses constituent devices of the interior air conditioning unit **1** therein. This case member **2** defines an air passage through which air is blown into the passenger compartment of the vehicle.

[0021] An interior/exterior air switching box **3** is installed in the most upstream portion of the air passage of the case member **2**. The interior/exterior air switching box **3** has an interior-air inlet port **3***a* and an exterior air inlet port **3***b*. An interior/exterior air switching door **3***c* is rotatably installed in the interior/exterior air switching box **3**.

[0022] The interior/exterior air switching door **3***c* is driven by a servomotor (not shown) to switch between an interior air mode, an exterior air mode and an interior/exterior air mode. In the interior air mode, interior air (air inside the passenger compartment) is introduced through the interior air inlet port **3***a* into the passenger compartment. In the exterior air mode, exterior air (air outside the passenger compartment) is introduced through the exterior air inlet port **3***b* into the passenger compartment. In the interior/exterior air mode, both the interior air and the exterior air are introduced into the passenger compartment.

[0023] An electric blower **4** is installed at a downstream side of the interior/exterior air switching box **3**. The electric blower **4** blows the air into the passenger compartment. The electric blower (second electric blower) **4** is an electrically-driven blower in which a well-known centrifugal multi-blade fan (sirocco fan) is driven by an electric motor **4**a. The rotational speed of the electric motor **4**a can be controlled by a control voltage outputted from an air conditioner controller **20**, which will be described later.

[0024] An evaporator **5** is installed at a downstream side of the electric blower **4**. The evaporator **5** is one of the constituent devices that constitute a refrigerant cycle system **10**, which will be described later. Moreover, the evaporator **5** evaporates low-pressure side refrigerant, which has flowed into the evaporator **5**, to absorb heat. Thereby, the evaporator **5** functions as a cooling heat exchanger that cools the air blown from the electric blower **4**.

[0025] A heater core **6** is installed at a downstream side of the evaporator **5** in an air flow direction. The heater core **6** is a heat exchanger for heating, which heats the air that has passed through the evaporator **5** by using heat of hot water that is heated by an electric heater etc. The hot water heated by the electric heater etc. is supplied into the heater core **6** by an electric pump (not shown).

[0026] Bypass passages **7** are arranged on the sides of the heater core **6**. The air flows through the bypass passages **7** to bypass the heater core **6**. Moreover, air mixing doors **8** are rotatably arranged on the sides of the heater core **6**. The air mixing doors **8** functions as an air temperature adjusting means. The air mixing door **8** are driven by a servomotor (not shown) so that the rotation position (opening degree) of the air mixing door **8** can be continuously adjusted.

[0027] By adjusting the opening degree of the air mixing door **8**, the ratio between the amount of air passing through the heater core **6** and the amount of air passing through the bypass passages **7** is adjusted. Thus, the temperature of the air on a downstream side of the heater core **6** is adjusted. In this embodiment, the bypass passages **7** are arranged on both sides of the heater core **6**. Accordingly, also the air mixing doors **8** are arranged on both sides of the heater core **6**, and the two air mixing doors **8** are controlled in conjunction with each other.

[0028] A defroster blowing-out port (not shown), a face blowing-out port (not shown) and a foot blowing-out port (not shown) are arranged at the most downstream part of the air passage of the case member **2**. Conditioned air is blown out toward a front window glass (windshield) of the vehicle through the defroster blowing-out port, toward an upper body of the passenger through the face blowing-out port, and toward feet of the passenger through the foot blowing-out port. Opening/closing doors are rotatably arranged at upstream sides of these blowing-out ports. The opening/closing doors open or close by being driven by a common servomotor through the medium of a link mechanism (not shown).

[0029] Next, the refrigerant cycle system **10** will be described. The refrigerant cycle system **10** has an electric compressor **11**, an exterior-side heat exchanger **13**, an electric expansion valve **16**, an accumulator **18**, etc., in addition to the above-mentioned evaporator **5**.

[0030] In the electric compressor **11**, an electric motor **11***a* and a compression mechanism **11***b*, which is driven by the electric motor **11***a*, are integrated. The electric motor **11***a* is located at a suction side of the electric compressor **11**, and is cooled by cold refrigerant that is drawn into the electric compressor **11**.

[0031] The electric motor **11***a* is a three phase AC motor. The compression mechanism **11***b* is a well-known scroll compression mechanism, for example. Moreover, the rotational speed of the electric motor **11***a* is variably controlled by an inverter unit **19**, which will be described later.

[0032] The exterior-side heat exchanger **13** is connected with a discharge side of the electric compressor **11**. At the exterior-side heat exchanger **13**, the refrigerant, which is discharged from the electric compressor **11** and has high temperature and high pressure, exchanges heat with the exterior air (air outside the passenger compartment). Thus, the exterior-side heat exchanger **13** functions as a heat-radiating heat exchanger. The exterior air is blown to the exterior-side heat exchanger **13** by an electrically-driven cooling fan (first electric blower) **13***a*. The cooling fan **13**a is driven by an electric motor **13***b*. The rotational speed of the electric motor **13***b* is controlled by the controlled voltage that is outputted from the air conditioner controller **20**, which will be described later.

[0033] The electric expansion valve **16**, which functions as a variable throttle mechanism, is connected with an outlet side of the exterior-side heat exchanger **13**. The electric expansion valve **16** functions as a pressure control valve. An opening degree of the pressure control valve is electrically controlled so that discharge refrigerant pressure Pd, which is the pressure of refrigerant at the discharge side of the electric compressor **11**, would be a target high pressure in a normal operation time of the refrigeration cycle. The electric expansion valve **16** also functions as a control valve, which inhibits temperature rise of the electric motor **11***a* of the electric compressor **11** when the temperature of the electric motor **11***a* is high.

[0034] Specifically, the electric expansion valve **16** includes an electric actuator mechanism **16***a* and a valve mechanism that is driven by the electric actuator mechanism **16***a*. A stepping motor serves as the electric actuator mechanism **16***a*, for example. An opening degree of the valve mechanism can be minutely adjusted in accordance with a working angle of the electric actuator mechanism **16***a*. The opening degree of the electric expansion valve **16** is controlled by the air conditioner controller **20**, which will be described later.

[0035] The above-mentioned evaporator **5** is connected with an outlet side of the electric type expansion valve **16**. The accumulator **18** is connected with the outlet side of the evaporator **5**. The accumulator **18** is a gas/liquid separation means, which separates the refrigerant discharged from the evaporator **5** into gas refrigerant (saturated gas-phase refrigerant) and liquid refrigerant (saturated liquid-phase refrigerant), and accumulates excessive refrigerant in the refrigeration cycle. The gas refrigerant separated in the accumulator **18** is introduced to the suction side of the electric compressor **11**.

[0036] An outline of an electrical control unit according to the first embodiment will be described hereafter. FIG. **2** is a block diagram showing the electric control portion. The air conditioner controller **20** is composed of a well-known microcomputer that includes a CPU, a ROM, a RAM, etc. and a periphery circuit of the microcomputer. The air conditioner controller **20** performs various calculations and processes based on a control program that is memorized in the ROM, to control operations of electric devices such as the inverter unit **19** of the electric compressor **11**, the electric motor **13***b* of the cooling fan **13***a*, the electric actuator mechanism **16***a* of the electric expansion valve **16** and the electric motor **4***a* of the electric blower **4**.

[0037] The inverter unit **19** of the electric compressor **11** will be briefly described hereafter. The electric motor **11***a* of the electric compressor **11**, which is a three phase AC motor, is rotationally driven by three phase AC electric power that is converted by and outputted from a power device **190** of the inverter unit **19**. The rotational speed of the electric motor **11***a* is minutely and variably controlled by an inverter control portion **191** (adjustable-speed drive controlling).

[0038] The inverter control portion **191** includes a CPU **192**, a communication circuit **193**, etc. The inverter control portion **191** communicates with the air conditioner controller **20** and controls the rotational speed of the electric motor **11***a* of the electric compressor **11** so that the rotational speed would be adjusted to an optimum value.

[0039] The inverter control portion **191** detects motor current, which is outputted to the electric motor **11***a*, and the rotational speed of the electric motor **11***a*, and outputs the detection values to the air conditioner controller **20**. The power source of the inverter unit **19** is a battery **21** that is mounted on the vehicle.

[0040] An input side of the air conditioner controller **20** is connected with a discharge pressure sensor **31**, an exterior-side refrigerant temperature sensor **32**, a post-evaporator air temperature sensor **33**, etc. The discharge pressure sensor **31** is for detecting the discharge refrigerant pressure Pd. The exterior-side refrigerant temperature sensor **32** is for detecting exterior-side refrigerant temperature Tho, which is the temperature of the refrigerant at the outlet side of the exterior-side heat exchanger **13**. The post-evaporator air temperature sensor **33** is for detecting blown-out air temperature Te, which is the temperature of the air blown from the evaporator **5**.

[0041] The detection signals of sensors **34**, which include an exterior air temperature sensor, an interior air temperature sensor, a solar radiation sensor, etc., are also inputted to the air conditioner controller **20**. These sensors **31-34** serve as various detection means in the first embodiment. Furthermore, an air conditioner operating panel **40** is arranged near the instrument board (instrument panel) in the passenger compartment. Various air conditioner operation signals are inputted from operation members of the air conditioner operating panel **40** to the air conditioner controller **20**.

[0042] Specifically, the various air conditioner operation signals inputted by the air conditioner operating panel **40** include an interior temperature setting signal, an airflow volume switching signal of the electric blower **4**, an air blow mode switching signal, an interior/exterior air introducing mode switching signal of the interior/exterior air switching box **3**, etc. The interior temperature setting signal is set by a temperature setting switch. The airflow volume switching signal is set by an airflow selector switch. The air blow mode switching signal is set by an air blow mode selector switch. The interior/exterior air introducing mode switching signal is set by an interior/exterior air selector switch.

[0043] Next, the operation of the refrigerant cycle system according to the first embodiment, which has the above-described construction, will be described hereafter. First, a basic operation of the refrigerant cycle system **10** will be described hereafter. When the operation member (air conditioner switch) of the air conditioner operating panel **40** is switched and the compressor activation commanding signal is generated, the electric motor **11***a* is electrically energized through the inverter unit **19**, and the electric motor **11***a* rotates. The driving force of the electric motor **11***a* is transmitted to the compression mechanism **11***b*, and the electric compressor **11** is driven.

[0044] The refrigerant is compressed by the electric compressor **11**, and the refrigerant has high temperature and high pressure. The refrigerant having the high temperature and the high pressure flows into the exterior-side heat exchanger **13**. At the exterior-side heat exchanger **13**, the refrigerant exchanges heat with the exterior air that is blown by the cooling fan **13***a*, so as to radiate heat to the exterior air.

[0045] Then, the refrigerant discharged from the exterior-side heat exchanger **13** is decompressed by the electric expansion valve **16** and brought into a gas-liquid two-phase state having low temperature and low pressure. The gas-liquid two-phase refrigerant having the low temperature and the low pressure flows into the evaporator **5**. At the evaporator **5**, the refrigerant is vaporized by absorbing heat of the air that is blown from the electric blower **4**. Thereby, the air blown from the electric blower **4** is cooled down by the evaporator **5**, and the cooled air can be blown into the passenger compartment.

[0046] Then, the low-pressure refrigerant that has passed through the evaporator **5** flows into the accumulator **18**. At the accumulator **18**, the low-pressure refrigerant is separated into the saturated liquid-phase refrigerant and the saturated gas-phase refrigerant. The saturated gas-phase refrigerant is introduced from an outlet of the accumulator **18** to the suction side of the electric compressor **11**. Then, the saturated gas-phase refrigerant is sucked into the electric compressor **11** and is compressed again.

[0047] Next, basic control process performed by the air conditioner controller **20** according to the first embodiment will be described hereafter. This control process begins when the air conditioner switch is turned on under the condition that a starter switch (not shown) of the vehicle is turned on.

[0048] First, a flag, a timer, etc. are initialized. Then, detection signals of the sensors **31-34** and operation signals of the air conditioner operating panel **40** are read in. Then, control states of the actuators **4***a*, **13***b*, **16***a*, **19** etc. are determined.

[0049] Specifically, a target blowing-out temperature TAO, at which the air should be blown into the passenger compartment, is calculated based on target air temperature Tset in the passenger compartment, interior air temperature Tr and exterior air temperature Tam. Furthermore, based on the target blowing-out temperature TAO, a target rotational speed of the electric blower **4** (voltage applied to the electric motor **4***a*), a target rotational speed of the cooling fan **13***a* of the exterior-side heat exchanger **13** (voltage applied to the cooling fan **13***a*), a target opening degrees of the air mixing doors **8** (control signals outputted to the servomotor for the air mixing doors **8**) are determined.

[0050] Furthermore, based on the target blowing-out temperature TAO, a target evaporator blowing-out temperature TEO is determined. The target blowing-out temperature TEO is a target value of cooling degree of the evaporator **5**. Then, a refrigerant discharge capacity of the electric compressor **11** (control signal that is outputted to the inverter unit **19**) is calculated so that the blowing-out air temperature Te of the evaporator **5** would approach the target evaporator blowing-out temperature TEO.

[0051] Moreover, based on the exterior-side refrigerant temperature Tho (temperature of the refrigerant at the outlet side of the exterior-side heat exchanger **13**), a target high pressure Po is determined. By the target high pressure Po, efficiency of the refrigeration cycle (COP) is maximized. The opening degree of the electric expansion valve **16** (control signal that is outputted to the electric actuator mechanism **16***a*) is determined so that the discharge refrigerant pressure Pd of the electric compressor **11** would become the above-mentioned target high pressure Po.

[0052] Then, output signals are outputted from the air conditioner controller **20** to the actuators **4***a*, **11***a*, **13***b*, **16***a*, etc. so as to realize the control states of the actuators **4***a*, **13***b*, **16***a*, **19** etc., which have been already determined.

[0053] In the electric compressor **11** in the first embodiment, the electric motor **11***a* is cooled by the cold refrigerant that is drawn into the electric compressor **11**. When the motor current, which is outputted from the inverter unit **19** to the electric motor **11***a*, is large and the rotational speed of the electric motor **11***a* is small, occasionally the electric motor **11***a* is not sufficiently cooled down by the cold refrigerant that is drawn into the electric compressor **11**, and the electric motor **11***a* can be in a high temperature state.

[0054] In such a case, the electric compressor **11** is stopped in a conventional refrigerant cycle system. In the first embodiment, the opening degree of the electric expansion valve **16** is controlled instead, to perform a temperature protection control for avoiding temperature rise of the electric motor **11***a* of the electric compressor **11**.

[0055] The temperature protection control for the electric motor **11***a* in the first embodiment will be described hereafter with reference to FIGS. **3**, **4**. FIG. **3** is a flowchart showing a process for setting the opening degree of the electric expansion valve **16**, which is performed by the air conditioner controller **20**. FIG. **4** is a control characteristic diagram showing the temperature of the electric motor **11***a* associated with the motor current and the rotational speed of the electric motor **11***a* of the electric compressor **11** in the first embodiment.

[0056] The process for setting the opening degree of the electric expansion valve **16**, which is shown in FIG. **3**, begins when the refrigeration cycle is started, that is, when the electric compressor **11** is started. First, at step S**100**, the air conditioner controller **20** reads the detection signals of the sensors, the various air conditioner operation signals sent from the air conditioner operating panel **40**, etc.

[0057] Specifically, the air conditioner controller **20** reads the discharge refrigerant pressure Pd that is detected by the discharge pressure sensor **31**, the exterior-side refrigerant temperature Tho (temperature of the refrigerant at the outlet side of the exterior-side heat exchanger **13**) that is detected by the exterior-side refrigerant temperature sensor **32**, the value of the motor current that is outputted from the inverter unit **19** to the electric motor **11***a*, the rotational speed of the electric motor **11***a*, etc.

[0058] Next, at step S**200**, the air conditioner controller **20** calculates a control amount of the opening degree of the electric expansion valve **16** so that the discharge refrigerant pressure Pd, which is detected by the discharge pressure sensor **31**, would become the target high pressure Po, which is determined based on the exterior-side refrigerant temperature Tho (temperature of the refrigerant at the outlet side of the exterior-side heat exchanger **13**) that is detected by the exterior-side refrigerant temperature sensor **32**. In the first embodiment, the opening degree of the electric expansion valve **16** is increased when the control amount of the opening degree is larger than zero, and the opening degree of the electric expansion valve **16** is decreased when the control amount of the opening degree is smaller than zero.

[0059] Moreover, in the first embodiment, the control characteristic shown in FIG. **4** is memorized beforehand in the ROM etc. of the air conditioner controller **20**. In this control characteristic, the temperature of the electric motor **11***a* is associated with the rotational speed and the motor current of the electric motor **11***a*, which are detected by the inverter unit **19**. The temperature of the electric motor **11***a* is inversely proportional to a flow rate of the refrigerant, namely, the rotational speed of the electric motor **11***a*. The temperature of the electric motor **11***a* is proportional to a heat generation in the electric motor **11***a*, namely, a square of the value of the motor current. For example, the temperature of the electric motor **11***a* becomes low when the rotational speed of the electric motor **11***a* is large and the motor current is small. The temperature of the electric motor **11***a* becomes high when the rotational speed of the electric motor **11***a* is small and the motor current is large.

[0060] In the first embodiment, the temperature of the electric motor **11***a* is calculated and detected based on the control characteristic. Alternatively, the temperature of the electric motor **11***a* may be calculated by inputting the rotational speed of the electric motor **11***a* and the value of the motor current into a computing equation, etc.

[0061] In the control characteristic, criterion values of the temperature of the electric motor **11***a* are specified in order to determine whether the temperature rise of the electric motor **11***a* should be avoided or not. Specifically, in the control characteristic of the first embodiment, first to third criterion values are specified as the criterion values of the temperature of the electric motor **11***a*, and a limit value of the temperature of the electric motor **11***a* is also specified.

[0062] The relation between the criterion values and the limit value is: (first criterion value)<(second criterion value)<(third criterion value)<(limit value). The first to third criterion values and the limit value of the temperature of the electric motor **11***a* are specified so that the rotational speed of the electric motor **11***a* would increases as the value of the motor current increases on a condition that the temperature of the electric motor **11***a* is kept at either one of the first to third criterion values and the limit value. A first criterion line, which indicates the rotational speed and the motor current of the electric motor **11***a* that correspond to the first criterion value, a second criterion line, which indicates the rotational speed and the motor current of the electric motor **11***a* that correspond to the second criterion value, a third criterion line, which indicates the rotational speed and the motor current of the electric motor **11***a* that correspond to the third criterion value, and a limit line, which indicates the rotational speed and the motor current of the electric motor **11***a* that correspond to the limit value, are in parallel with each other.

[0063] The first to third criterion lines and the limit line separate the temperature of the electric motor **11***a* of the electric compressor **11** into ranges A-D and an off-limit range. Specifically, in the range A, the temperature of the electric motor **11***a* is lower than the first criterion value on the basis of the control characteristic that associates the temperature of the electric motor **11***a* with the rotational speed and the motor current of the electric motor **11***a*. In the range B, the temperature of the electric motor **11***a* is equal to or higher than the first criterion value and is lower than the second criterion value. In the range C, the temperature of the electric motor **11***a* is equal to or higher than the second criterion value and is lower than the third criterion value. In the range D, the temperature of the electric motor **11***a* is equal to or higher than the third criterion value and is lower than the limit value. In the off-limit range, which is a diagonally shaded area in FIG. **4**, the temperature of the electric motor **11***a* is equal to or higher than the limit value.

[0064] The ranges A-D and the off-limit range are indices that indicate the states of the temperature of the electric motor **11***a* of the electric compressor **11**. The range A indicates a normal state of the temperature of the electric motor **11***a*. The off-limit range indicates an abnormal state of the temperature of the electric motor **11***a*, in which the temperature of the electric motor **11***a* is excessively high (at 120° C., for example) and an insulation failure of a winding can occur in the electric motor **11***a*. The ranges B-D are set between the range A and the off-limit range, and indicate a state where the temperature protection control for the electric motor **11***a* is necessary.

[0065] At step S**300** in FIG. **3**, the air conditioner controller **20** calculates and detects current temperature of the electric motor **11***a* in accordance with the rotational speed and the motor current of the electric motor **11***a* on the basis of the control characteristic. Then, the air conditioner controller **20** calculates the current temperature of the electric motor **11***a* is in which range of the above-mentioned control characteristic. Then, at step S**400**, the air conditioner controller **20** determines whether the temperature of the electric motor **11***a*, which has been calculated at step S**300**, is in the range A or not.

[0066] If it is determined at step S**400** that the temperature of the electric motor **11***a* is in the range A, the air conditioner controller **20** sets the control amount that has been calculated at step S**200** as the control amount of the opening degree of the electric expansion valve **16** (step S**500**). That is, the discharge refrigerant pressure Pd of the electric compressor **11** can be maintained at the target high pressure Po, which realizes the optimal control of the refrigeration cycle.

[0067] If it is not determined at step S**400** that the temperature of the electric motor **11***a* is in the range A, the air conditioner controller **20** determines at step S**410** whether the control amount of the opening degree of the electric expansion valve **16**, which has been calculated at step S**200**, is larger than zero or not. If it is determined at step S**410** that the control amount is smaller than zero, the opening degree of the electric expansion valve **16** is being controlled to decrease. Thus, at step S**420**, the air conditioner controller **20** sets the control amount at zero so as to change the control amount to a value that will not change the opening degree of the electric expansion valve **16**. If it is determined at step S**410** that the control amount is larger than or equal to zero, the air conditioner controller **20** does not change the control amount, and the process goes to step S**430**.

[0068] Next, at step S**430**, the air conditioner controller **20** determines whether the temperature of the electric motor **11***a* is in the range B or not. If it is determined at step S**430** that the temperature of the electric motor **11***a* is in the range B, the process goes to step S**500**, and the air conditioner controller **20** sets the control amount that is larger than or equal to zero as the control amount of the opening degree of the electric expansion valve **16**.

[0069] Thus, if the temperature of the electric motor **11***a* is in the range B, at least the opening degree of the electric expansion valve **16** is controlled not to decrease. That is, at least the increase of the discharge refrigerant pressure Pd of the electric compressor **11** is inhibited, so that it is possible to avoid the load increase of the electric compressor **11** and the temperature rise of the electric motor **11***a*.

[0070] If it is not determined at step S**430** that the temperature of the electric motor **11***a* is in the range B, the air conditioner controller **20** determines at step S**440** whether the temperature of the electric motor **11***a* is in the range C or not. If it is determined at step S**440** that the temperature of the electric motor **11***a* is in the range C, at step S**450**, the air conditioner controller **20** adds a first predetermined value alpha to the control amount of the opening degree of the electric expansion valve **16**, which has been calculated at step S**200**, or adds the first predetermined value alpha to the control amount that has been set at zero at step S**420**.

[0071] Then, the process goes to step S**500**, and the air conditioner controller **20** sets the control amount, to which the first predetermined value alpha is added, as the control amount of the opening degree of the electric expansion valve **16**. Thus, if the temperature of the electric motor **11***a* is in the range C, the opening degree of the electric expansion valve **16** is controlled to increase. That is, the discharge refrigerant pressure Pd of the electric compressor **11** is decreased, so that it is possible to decrease the load of the electric compressor **11** and to avoid the temperature rise of the electric motor **11***a*.

[0072] If it is not determined at step S**440** that the temperature of the electric motor **11***a* is in the range C, the air conditioner controller **20** determines at step S**460** whether the temperature of the electric motor **11***a* is in the range D or not. If it is determined at step S**460** that the temperature of the electric motor **11***a* is in the range D, at step S**470**, the air conditioner controller **20** adds a second predetermined value beta to the control amount of the opening degree of the electric expansion valve **16**, which has been calculated at step S**200**, or adds the second predetermined value beta to the control amount that has been set at zero at step S**420**.

[0073] Then, the process goes to step S**500**, and the air conditioner controller **20** sets the control amount, to which the second predetermined value beta is added, as the control amount of the opening degree of the electric expansion valve **16**. The second predetermined value beta, which is added at step S460, is a value larger than the first predetermined value alpha, which is added at step S450 ((first predetermined value alpha)<(second predetermined value beta)). Thus, if the temperature of the electric motor 11*a* is in the range D, the opening degree of the electric expansion valve 16 is controlled to increase more than when the temperature of the electric motor 11*a* is in the range C.

[0074] That is, by gradually decreasing the discharge refrigerant pressure Pd of the electric compressor 11, it become possible to avoid the temperature rise of the electric motor 11*a* by decreasing the load of the electric compressor 11, and to prevent a sudden change of the discharge refrigerant pressure Pd of the electric compressor 11, which degrades the air conditioning feeling etc. in the passenger compartment.

[0075] If it is not determined at step S460 that the temperature of the electric motor 11*a* is in the range D, the air conditioner controller 20 determines at step S480 that the temperature of the electric motor 11*a* is abnormal, and memorizes the abnormality in the ROM etc. of the air conditioner controller 20.

[0076] If the temperature of the electric motor 11*a* is in the off-limit range, it is anticipated that the refrigerant cycle system 10 can break down. Therefore, the operation of the electric compressor 11 is stopped. The determination processes at steps S400, S430, S440, S460 correspond to a protection determining means, and the processes at steps S420, S450, S470 correspond to a motor protection control means.

[0077] As described above, when the temperature of the electric motor 11*a* of the electric compressor 11 is equal to or higher than the first criterion value, at least the opening degree of the electric expansion valve 16 is controlled not to decrease. Thus, it is possible to avoid the increase of the discharge refrigerant pressure Pd of the electric compressor 11. Thereby, at least the increase of the load of the electric compressor 11 is avoided, and it is possible to avoid the increase of the motor current that is outputted to the electric motor 11*a*. Therefore, it is possible to perform the temperature protection control for avoiding temperature rise of the electric motor 11*a* without stopping the electric compressor 11.

[0078] Moreover, the temperature of the electric motor 11*a* is calculated and detected on the basis of the control characteristic that associates the temperature of the electric motor 11*a* with the rotational speed and the motor current of the electric motor 11*a*. Thus, it is possible to perform the temperature protection control for avoiding temperature rise of the electric motor 11*a* when the temperature of the electric motor 11*a* is equal to or higher than a criterion value.

[0079] Moreover, in detecting the temperature of the electric motor 11*a* on the basis of the control characteristic, it is possible to perform the temperature protection control for avoiding temperature rise of the electric motor 11*a* without providing the electric motor 11*a* with a detecting device exclusively for detecting the temperature of the electric motor 11*a*. Thus, it is possible to simplify the construction of the electric compressor 11.

[0080] Moreover, by specifying more than two criterion values (the first to third criterion values) as the criterion value in the control characteristic, it is possible to gradually adjust the opening degree of the electric expansion valve 16. Therefore, it is possible to inhibit the air conditioning feeling etc. in the passenger compartment from becoming degraded. In the first embodiment, the first to third criterion values are specified as the criterion value. The present invention is not limited to this, and it is also possible to increase or decrease the number of the criterion value(s).

Second Embodiment

[0081] Next, a second embodiment of the present invention will be described hereafter, referring to FIGS. 5-7. Elements that are substantially the same as or equivalent to those in the first embodiment have the same reference numerals as in the first embodiment, and are not described again. FIG. 5 is a schematic diagram showing an entire construction of a refrigerant cycle system according to the second embodiment, which is applied to a vehicular air conditioning system. The refrigerant cycle system 10 according to the second embodiment is configured as a heat pump refrigeration cycle that can be switched between a cooling operation mode and a heating operation mode.

[0082] As shown in FIG. 5, in the second embodiment, a heater core 6 is arranged in a case member 2 of an interior air conditioning unit 1. The heater core 6 is one of the constituent devices that constitute the refrigerant cycle system 10. The heater core 6 functions as a use-side heat exchanger, which heats the air that has passed through an evaporator 5 by using the refrigerant having high temperature and high pressure as a heat source. The heater core 6 functions also as a heat-radiating heat exchanger, which cools the refrigerant by radiating heat to the air that has passed through the evaporator 5.

[0083] The refrigerant cycle system 10 according to the second embodiment has the evaporator 5, the heater core 6, an electric compressor 11, a first electric expansion valve 12, an exterior-side heat exchanger 13, an interior heat exchanger 15, a second electric expansion valve 16, which corresponds to the electric expansion valve in the first embodiment, an accumulator 18, etc. In the following description, the heater core 6 is explained as a use-side heat exchanger.

[0084] An inlet side of the above-mentioned use-side heat exchanger 6 is connected with a discharge side of the electric compressor 11. The first electric expansion valve 12, which functions as a variable throttle mechanism, is connected with an outlet side of the use-side heat exchanger 6.

[0085] The first electric expansion valve 12 functions also as a high pressure control valve. The opening degree of the high pressure control valve is electrically controlled by control signals that are outputted from an air conditioner controller 20 so that discharge refrigerant pressure Pd of the refrigeration cycle would become a target high pressure Po in the heating operation mode, which will be described later. The first electric expansion valve 12 includes an electric actuator mechanism 12*a* and a valve mechanism.

[0086] The exterior-side heat exchanger 13 is connected with an outlet side of the first electric expansion valve 12. The refrigerant cycle system 10 according to the second embodiment has a first bypass passage 14*a*. The first bypass passage 14*a* connects the outlet side of the use-side heat exchanger 6 directly with an inlet side of the exterior-side heat exchanger 13 so that the refrigerant can bypass the first electric expansion valve 12. A first open/close valve 14 is arranged in the first bypass passage 14*a* to open and close the first bypass passage 14*a*. The first open/close valve 14 is an electromagnetic valve that is controlled to be opened and closed by control voltage that is outputted from the air conditioner controller 20.

[0087] In the cooling operation mode, which will be described later, the exterior-side heat exchanger 13 functions as a heat-radiating heat exchanger that cools the refrigerant by radiating heat of the refrigerant to the exterior air in an analogous fashion as in the first embodiment. In the heating operation mode, the exterior-side heat exchanger **13** functions as a heat-absorbing heat exchanger that vaporizes the refrigerant by absorbing heat from the exterior air.

[0088] A first refrigerant passage **15***a* of the interior heat exchanger **15** is connected with an outlet side of the exterior-side heat exchanger **13**. In the cooling operation mode, which will be described later, the interior heat exchanger **15** cools the refrigerant at the outlet side of the exterior-side heat exchanger **13** by exchanging heat between the refrigerant at the outlet side of the exterior-side heat exchanger **13**, which passes through the first refrigerant passage **15***a* of the interior heat exchanger **15**, and the refrigerant at a suction side of the electric compressor **11**, which passes through a second refrigerant passage **15***b* of the interior heat exchanger **15**.

[0089] The second electric expansion valve **16**, which functions as a variable throttle mechanism, is arranged at an outlet side of the first refrigerant passage **15***a* of the interior heat exchanger **15**. The second electric expansion valve **16** has substantially the same construction as the first electric expansion valve **12**, and has an electric actuator mechanism **16***a* and a valve mechanism.

[0090] In the cooling operation mode, which will be described later, the second electric expansion valve **16** functions also as a high pressure control valve. The opening degree of the high pressure control valve is electrically controlled by the control signals that are outputted from the air conditioner controller **20** so that the discharge refrigerant pressure Pd would become the target high pressure Po. The evaporator **5** is connected with an outlet side of the second electric expansion valve **16**.

[0091] Furthermore, the refrigerant cycle system **10** according to the second embodiment has a second bypass passage **17***a*. The second bypass passage **17***a* connects an inlet side of the first refrigerant passage **15***a* of the interior heat exchanger **15** directly with an outlet side of the evaporator **5** so that the refrigerant can bypass the second electric expansion valve **16**. Moreover, a second open/closing valve **17** is arranged in the second bypass passage **17***a* to open and close the second bypass passage **17***a*.

[0092] The second open/close valve **17** has substantially the same construction as the first open/close valve **14**, and is an electromagnetic valve that is controlled to be opened and closed by control voltage that is outputted from the air conditioner controller **20**. The accumulator **18** is arranged at a downstream side of the evaporator **5** and the second bypass passage **17***a*. Moreover, an inlet side of the second refrigerant passage **15***b* of the interior heat exchanger **15** is connected with an outlet of the accumulator **18**, from which gas-phase refrigerant flows out. The suction side of the electric compressor **11** is connected with an outlet side of the second refrigerant passage **15***b*.

[0093] The air conditioner controller **20** performs various calculations and processes based on a control program that is memorized in the ROM, to control operations of the above-mentioned actuators **4***a*, **11***b*, **12***a*, **13***a*, **14**, **16***a*, **17**, etc.

[0094] Moreover, an input side of the air conditioner controller **20** is connected with a suction pressure sensor **35**, a suction refrigerant temperature sensor **36**, a discharge refrigerant temperature sensor **37**, a use-side refrigerant temperature sensor **38**, etc., in addition to the construction of the first embodiment. The suction pressure sensor **35** is for detecting suction refrigerant pressure Ps of the electric compressor **11**. The suction refrigerant temperature sensor **36** is for detecting suction refrigerant temperature sensor Ts of the electric compressor **11**. The discharge refrigerant temperature sensor **37** is for detecting discharge refrigerant temperature Td of the electric compressor **11**. The use-side refrigerant temperature sensor **38** is for detecting for detecting use-side refrigerant temperature Tco. Detection signals of these sensors **35**-**38**, etc. are inputted to the input side of the air conditioner controller **20**.

[0095] Furthermore, an air conditioner operating panel **40** is provided with a cooling/heating selecting switch, etc. The cooling/heating selecting switch is for selectively switching between the heating operation mode, in which the air to be blown into the passenger compartment is heated, and the cooling operation mode, in which the air to be blown into the passenger compartment is cooled.

[0096] Next, the operation of the refrigerant cycle system **10** according to the second embodiment, which has the above-described construction, will be described hereafter. First, a basic operation of the refrigerant cycle system **10** when the cooling/heating selecting switch of the air conditioner operating panel **40** is switched to the cooling operation mode will be described hereafter.

[0097] In the cooling operation mode, the first open/close valve **14** is opened, the first electric expansion valve **12** is fully closed, and the second open/close valve **17** is closed. Thus, in the cooling operation mode, the refrigerant, which has been compressed in the electric compressor **11** and has high temperature and high pressure, radiates heat to the air in the use-side heat exchanger (heater core) **6**. The refrigerant that has flowed out from the use-side heat exchanger **6** flows into the exterior side heat exchanger **13** through the first bypass passage **14***a*, and further radiates heat to the exterior air and is cooled.

[0098] The refrigerant that has flowed out from the exterior-side heat exchanger **13** flows into the first refrigerant passage **15***a* of the interior heat exchanger **15**, and exchanges heat with the suction refrigerant of the electric compressor **11**, which is going to be sucked into the electric compressor **11** and is passing through the second refrigerant passage **15***b*, and is further cooled, so that the enthalpy of the refrigerant is decreased. Thus, the enthalpy difference (refrigeration capacity) between the refrigerant at the inlet of the evaporator **5** and the refrigerant at the outlet of the evaporator **5** is increased.

[0099] The refrigerant that has flowed out from the first refrigerant passage **15***a* of the interior heat exchanger **15** is depressurized at the second electric expansion valve **16**. The refrigerant that has been depressurized at the second electric expansion valve **16** flows into the evaporator **5**, and absorbs heat from the air and evaporates. Therefore, the air that is blown into the passenger compartment is cooled. Thus, the refrigerant that has flowed out from the evaporator **5** flows into the accumulator **18**, and gas-phase refrigerant is separated from liquid-phase refrigerant. Furthermore, the gas-phase refrigerant that has flowed out from the accumulator **18** is sucked into the electric compressor **11** through the second refrigerant passage **15***b* of the interior heat exchanger **15**.

[0100] In the heating operation mode, the first open/close valve **14** is closed, the second open/close valve **17** is opened and the second electric expansion valve **16** is fully closed. Thus, in the heating operation mode, the refrigerant, which has been compressed in the electric compressor **11** and has high temperature and the high pressure, radiates heat to the air in the use-side heat exchanger **6**.

[0101] The refrigerant that has flowed out from the use-side heat exchanger **6** is depressurized at the first electric expansion valve **12**. The refrigerant that has been depressurized at the first electric expansion valve **12** absorbs heat at the exterior-side heat exchanger **13** from the exterior air, and is vaporized. The refrigerant that has flowed out from the exterior-side heat exchanger **13** flows through the second bypass passage **17***a*, the accumulator **18** and the second refrigerant passage **15***b* of the interior heat exchanger **15** in sequence, and is sucked into the electric compressor **11**.

[0102] Next, the temperature protection control in the second embodiment, in which the first and second electric expansion valves **12**, **16** operates to protect the electric motor **11***a* of the electric compressor **11**, will be described hereafter with reference to FIGS. **6**, **7**A, **7**B. FIG. **6** is a flowchart showing a process for setting the opening degrees of the first and second electric expansion valves **12**, **16**, which is performed by the air conditioner controller **20** in the second embodiment. FIGS. **7**A, **7**B are control characteristic diagrams showing criterion values of the motor current of the electric motor **11***a* of the electric compressor **11** in the second embodiment, which are set in association with the rotational speed of the electric motor **11***a*. FIG. **7**A shows the control characteristic diagram in the cooling operation mode. FIG. **7**B shows the control characteristic diagram in the heating operation mode.

[0103] First, at step S**100**, the air conditioner controller **20** reads the detection signals of the sensors, the various air conditioner operation signals sent from the air conditioner operating panel **40**, etc.

[0104] Specifically, the air conditioner controller **20** reads discharge refrigerant pressure Pd that is detected by a discharge pressure sensor **31**, exterior-side refrigerant temperature Tho that is detected by an exterior-side refrigerant temperature sensor **32**, use-side refrigerant temperature Tco that is detected by a use-side refrigerant temperature sensor **38**, the value of the motor current that is outputted from the inverter unit **19** to the electric motor **11***a*, the rotational speed of the electric motor **11***a*, etc. Moreover, the air conditioner controller **20** detects whether the cooling/heating selecting switch of the air conditioner operating panel **40** is switched to the cooling operation mode or to the-heating operation mode.

[0105] Next, at step S**110**, the air conditioner controller **20** determines whether the cooling/heating selecting switch of the air conditioner operating panel **40** is switched to the cooling operation mode or not. If it is determined that the cooling/heating selecting switch of the air conditioner operating panel **40** is switched to the cooling operation mode, the air conditioner controller **20** calculates at step S**210** a control amount of the opening degree of the second electric expansion valve **16** so that the discharge refrigerant pressure Pd of the electric compressor **11** can become the target high pressure Po, which is determined based on the exterior-side refrigerant temperature Tho of the exterior-side heat exchanger **13**.

[0106] In the second embodiment, the refrigerant that has flowed out from the exterior-side heat exchanger **13** exchanges heat at the interior heat exchanger **15** with the suction refrigerant of the electric compressor **11** in the cooling operation mode. Therefore, the suction refrigerant of the electric compressor **11** is heated by the refrigerant that has flown out from the exterior-side heat exchanger **13**, and the temperature of the suction refrigerant is higher than that in the heating operation mode. Accordingly, in the cooling operation mode, the discharge refrigerant temperature is higher than that in the heating operation mode, so that the temperature of the electric motor **11***a* rises more than in the heating operation mode. That is, the temperature of the suction refrigerant of the electric compressor **11** in the cooling operation mode is different from that in the heating operation mode, and the temperature of the electric motor **11***a* in the cooling operation mode is different from that in the heating operation mode even if each the motor current and the rotational speed of the electric motor **11***a* is the same.

[0107] For this reason, in the second embodiment, the control characteristic for the cooling operation mode (see FIG. **7**A) and the control characteristic for the heating operation mode (see FIG. **7**B) are separately memorized beforehand in the ROM etc. of the air conditioner controller **20**. As shown in FIGS. **7**A, **7**B, the criterion temperature in the control characteristic for the cooling operation mode is lower than the criterion temperature in the control characteristic for the heating operation mode. Two or more control characteristics in which the criterion values are different are memorized in ROM etc. of the air conditioner controller **20** for each operation mode.

[0108] Next, at step S**310**, the air conditioner controller **20** selects the control characteristic for the cooling operation mode. Then, based on the selected control characteristic, the air conditioner controller **20** calculates and detects the temperature of the electric motor **11***a* from the detected rotational speed and the motor current of the electric motor **11***a*. Moreover, the air conditioner controller **20** calculates the detected temperature of the electric motor **11***a* is in which range of the control characteristic for the cooling operation mode, and the process goes to step S**400**.

[0109] If it is determined at step S**110** that the cooling/heating selecting switch of the air conditioner operating panel **40** is switched to the heating operation mode, the air conditioner controller **20** calculates at step S**220** a control amount of the opening degree of the first electric expansion valve **12** so that the discharge refrigerant pressure Pd of the electric compressor **11** can become the target high pressure Po, which is determined based on the exterior-side refrigerant temperature Tho of the exterior-side heat exchanger **13**.

[0110] Next, at step S**310**, the air conditioner controller **20** selects the control characteristic for the cooling operation mode. Then, based on the selected control characteristic, the air conditioner controller **20** calculates and detects the temperature of the electric motor **11***a* from the detected rotational speed and the motor current of the electric motor **11***a*. Moreover, the air conditioner controller **20** calculates the detected temperature of the electric motor **11***a* is in which range of the control characteristic for the heating operation mode, and the process goes to step S**400**. The processes at steps S**310**, S**320** correspond to a control characteristic selector.

[0111] As explained above, in each operation mode, a control characteristic adapted for the operation mode is selected from two or more control characteristics in which the criterion values are different, and the temperature of the electric motor **11***a* is detected based on the selected control characteristic. By determining whether the detected temperature of the electric motor **11***a* is larger than (or equal to) the criterion value of the selected control characteristic or not, it is possible to perform the determination in the temperature protection control for the electric motor **11***a*. Thereby, the reliability of the temperature protection control of the electric motor **11***a* is raised.

Third Embodiment

[0112] Next, a third embodiment of the present invention will be described hereafter. Elements that are substantially the same as or equivalent to those in the first and second embodiments have the same reference numerals as in the first and second embodiments, and are not described again.

[0113] In the above-described second embodiment, a certain control characteristic is selected in accordance with the operation mode, and the temperature of the electric motor **11***a* is calculated and detected from the detection value of the inverter unit **19**, on the basis of the selected control characteristic. In contrast, in the third embodiment, two or more control characteristics in which the criterion values are different are memorized beforehand in ROM etc. of the air conditioner controller **20**. Then, a certain control characteristic is selected from the two or more control characteristics in accordance with a degree of superheat of the refrigerant at the suction side of the electric compressor **11**, and the temperature of the electric motor **11***a* is calculated from the detection value of the inverter unit **19**.

[0114] Specifically, suction refrigerant pressure Ps of the electric compressor **11** is detected by the suction pressure sensor **35**, and suction refrigerant temperature sensor Ts of the electric compressor **11** is detected by the suction refrigerant temperature sensor **36**. Then, saturated vapor temperature of the refrigerant is calculated from the detected suction refrigerant pressure Ps, and the degree of superheat SH of the refrigerant at the suction side of the electric compressor **11** is calculated from the suction refrigerant temperature Ts and the saturated vapor temperature. Alternatively, the suction refrigerant pressure Ps may be evaluated from blown-out air temperature Te of the evaporator **5**, which is detected by a post-evaporator air temperature sensor **33**.

[0115] If the degree of superheat SH of the refrigerant at the suction side of the electric compressor **11** is large, the temperature of the electric motor **11***a* rises. Therefore, a control characteristic in which the criterion value is set low is selected from two or more control characteristics. If the degree of superheat SH of the refrigerant at the suction side of the electric compressor **11** is small, the temperature of the electric motor **11***a* does not rise so much. Therefore, a control characteristic in which the criterion value is set high is selected from two or more control characteristics.

[0116] As explained above, based on the degree of superheat SH of the refrigerant at the suction side of the electric compressor **11**, a certain control characteristic is selected from predetermined two or more control characteristics in which the criterion values are different and the temperature of the electric motor **11***a* is calculated and detected based on the certain control characteristic. Thus, it is possible to perform the determination in the temperature protection control for the electric motor **11***a*. Thereby, the reliability of the temperature protection control of the electric motor **11***a* is raised.

[0117] Here, the control process in the third embodiment is applicable not only to the heat pump refrigerant cycle system described in the second embodiment, but also to the refrigerant cycle system described in the first embodiment.

Other Embodiments

[0118] The present invention is not limited to the above-described embodiments, and may be modified variously as follows.

[0119] (1) In the above-described embodiments, the temperature of the electric motor **11***a* of the electric compressor **11** is calculated and detected, using the control characteristic that associates the temperature of the electric motor **11***a* with the rotational speed and the motor current of the electric motor **11***a*. The present invention is not limited to this configuration. For example, the temperature of the electric motor **11***a* may be detected by a temperature sensor for detecting intra-motor temperature of the electric motor **11***a*, a temperature sensor for detecting temperature of a housing of the electric motor **11***a*, etc.

[0120] (2) In the above-described embodiments, the opening degrees of the electric expansion valves **12**, **16** are directly adjusted in the temperature protection control for the electric motor **11***a* of the electric compressor **11**. The present invention is not limited to this configuration. For example, the discharge refrigerant pressure Pd of the electric compressor **11** may be lowered by lowering the target high pressure that is determined based on the temperature (exterior-side refrigerant temperature) Tho of the refrigerant at the outlet side of the exterior-side heat exchanger **13** or the use-side heat exchanger **6**, which acts as the heat-radiating heat exchanger.

[0121] (3) In the above-described embodiments, the temperature protection control for the electric motor **11***a* of the electric compressor **11** is performed by controlling the opening degree of the electric expansion valve **16** not to decrease when the temperature protection for the electric motor **11***a* of the electric compressor **11** is necessary. Alternatively, it is also possible to raise the rotational speed of the electric motor **13***b* of the cooling fan (first electric blower) **13***a* in addition to the control of the opening degree of the electric expansion valve **16**.

[0122] By raising the rotational speed of the cooling fan **13***a*, the temperature of the refrigerant at the outlet side of the heat-radiating heat exchanger **6**, **13** is lowered, and the target high pressure is lowered. Thereby, the pressure (discharge refrigerant pressure Pd) of the refrigerant at the outlet side of the electric compressor **11** is lowered, and the temperature rise of the electric motor **11***a* is avoided.

[0123] (4) Moreover, it is also possible to lower the rotational speed of the electric motor **4***a* of the electric blower (second electric blower) **4** when the temperature protection for the electric motor **11***a* of the electric compressor **11** is necessary.

[0124] By lowering the rotational speed of the electric blower **4**, the cooling capacity of the evaporator **5** is raised, and the degree of superheat of the refrigerant at the suction side of the electric compressor **11** is lowered. Thereby, the pressure (suction refrigerant pressure Ps) of the refrigerant at the suction side of the electric compressor **11** is lowered, and the temperature rise of the electric motor **11***a* is avoided.

[0125] (5) Further, the interior/exterior air switching door **3***c* may be switched to the interior air mode when the temperature protection for the electric motor **11***a* of the electric compressor **11** is necessary. By switching the interior/exterior air switching door **3***c* to the interior air mode, the cooling capacity of the evaporator **5** is lowered, and the degree of superheat of the refrigerant at the suction side of the electric compressor **11** is lowered. Thereby, the pressure (suction refrigerant pressure Ps) of the refrigerant at the suction side of the electric compressor **11** is lowered, and the temperature rise of the electric motor **11***a* is avoided.

[0126] (6) In the above-described second embodiment, different control characteristics, in which the criterion values are different, are selected for the cooling operation mode and the heating operation mode. The present invention is not limited to this configuration. For example, the control characteristic for the heating operation mode may be applied in dehumidifying operation mode. A control characteristic for the dehumidifying operation mode may be selected in the dehumidifying operation mode.

[0127] (7) Moreover, in the above-described second embodiment, even in the cooling operation mode, the degree of superheat of the refrigerant at the suction side of the electric compressor **11** is small when the electric compressor **11** has just started. Therefore, the same control characteristic as that for the heating operation mode may be selected when the degree of superheat of the refrigerant is smaller than a predetermined value, and the same control characteristic as that for the cooling operation mode may be selected when the degree of superheat of the refrigerant is larger than a predetermined value.

[0128] (8) Moreover, the above-described refrigerant cycle system **10** may be applied to an ejector cycle system that is publicly known by the documents such as JP3322263B1, which corresponds to U.S. Pat. Nos. 6,477,857 and 6,574,987. In this case, the variable throttle mechanism is replaced by an ejector provided with a variable needle.

[0129] (9) In the above-described embodiments, the refrigerant cycle system **10** according to the present invention is applied to a vehicular air conditioning system. The present invention is not limited to these examples. For example, the refrigerant cycle system according to the present invention may be applied to a fixed air conditioning system for home use or business use. Moreover, the refrigerant cycle system may be applied not only to an air conditioning system that can be switched between the cooling operation mode and the heating operation mode but also to a dedicated cooling system.

[0130] (10) Moreover, in the above-described refrigerant cycle system **10**, the kind of the refrigerant is not specified. The refrigerant may be chlorofluorocarbons, chlorofluorocarbon substitutes such as HC refrigerants, carbon dioxide (CO_2) that can be applied to both a supercritical vapor compression refrigerant cycle system and a subcritical vapor compression refrigerant cycle system, etc.

[0131] Additional advantages and modifications will readily occur to those skilled in the art. The invention in its broader terms is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described.

What is claimed is:

1. A refrigerant cycle system comprising:

an electric compressor that includes a compression mechanism, which sucks and compresses refrigerant, and an electric motor, which drives the compression mechanism and is cooled by the refrigerant at a suction side of the compression mechanism;

a variable throttle mechanism that decompresses the refrigerant discharged from the electric compressor;

a motor temperature detector that detects a temperature of the electric motor;

a motor protection determiner that determines whether the temperature of the electric motor detected by the motor temperature detector is equal to or higher than a criterion value; and

a motor protection controller that controls the variable throttle mechanism so that opening degree of the variable throttle mechanism does not decrease when the motor protection determiner determines that the temperature of the electric motor is equal to or higher than the criterion value.

2. The refrigerant cycle system according to claim **1**, further comprising a drive circuit that controls operation of the electric motor, wherein:

the drive circuit detects a motor current, which is an electric current outputted to the electric motor, and a rotational speed of the electric motor; and

the motor temperature detector detects the temperature of the electric motor by calculating the temperature of the electric motor from the rotational speed and the motor current of the electric motor, which are detected by the drive circuit, with reference to a control characteristic data map, which is prepared in advance and indicates a relationship of the temperature of the electric motor with respect to the rotational speed and the motor current of the electric motor.

3. The refrigerant cycle system according to claim **2**, wherein:

the criterion value is specified in the control characteristic data map to corresponds to the rotational speed and the motor current of the electric motor; and

the motor protection determiner determines whether the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the criterion value specified in the control characteristic data map.

4. The refrigerant cycle system according to claim **3**, wherein:

the criterion value specified in the control characteristic data map is a first criterion value;

a second criterion value that is higher than the first criterion value is specified in the control characteristic data map;

the motor protection determiner determines whether the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the first criterion value;

the motor protection determiner further determines whether the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the second criterion value when the motor protection determiner determines that the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the first criterion value;

the motor protection controller controls the variable throttle mechanism so that the opening degree of the variable throttle mechanism does not decrease when the motor protection determiner determines that the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the first criterion value and is lower than the second criterion value; and

the motor protection controller controls the variable throttle mechanism so that the opening degree of the variable throttle mechanism increases when the motor protection determiner determines that the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the second criterion value.

5. The refrigerant cycle system according to claim **3**, further comprising:

a suction refrigerant superheating degree detector that detects a degree of superheat of the refrigerant at the suction side of the electric compressor; and

a control characteristic selector that selects one control characteristic data map from among a plurality of control characteristic data maps, each of which is prepared in advance and indicates a relationship of the temperature of the electric motor with respect to the rotational speed and the motor current of the electric motor, on a basis of the degree of superheat of the refrigerant detected by the suction refrigerant superheating degree detector, wherein

the motor protection determiner determines whether the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the criterion value specified in the one control characteristic data map.

6. The refrigerant cycle system according to claim **3**, wherein the refrigerant cycle system is a heat pump system that operates in a cooling operation mode in which the refrigerant cools heat-exchange target fluid and in a heating operation mode in which the refrigerant heats the heat-exchange target fluid, the refrigerant cycle system further comprising

a control characteristic selector that selects a first control characteristic data map in the cooling operation mode from among a plurality of control characteristic data maps, each of which is prepared in advance and indicates a relationship of the temperature of the electric motor with respect to the rotational speed and the motor current of the electric motor, and selects a second control characteristic data map in the heating operation mode from among the plurality of control characteristic data maps so that the criterion value specified in the first control characteristic data map is lower than the criterion value specified in the second control characteristic data map, wherein

the motor protection determiner determines whether the temperature of the electric motor calculated by the motor temperature detector is equal to or higher than the criterion value specified in the first control characteristic data map or the second control characteristic data map that is selected by the control characteristic selector.

7. The refrigerant cycle system according to claim **1**, further comprising a heat-radiating heat exchanger that cools the refrigerant at a discharge side of the electric compressor, wherein:

the variable throttle mechanism decompresses the refrigerant at an outlet side of the heat-radiating heat exchanger so that a pressure of the refrigerant at the discharge side of the electric compressor becomes closer to a target high pressure that is determined on a basis of a temperature of the refrigerant at the outlet side of the heat-radiating heat exchanger; and

the motor protection controller lowers the target high pressure when the temperature of the electric motor detected by the motor temperature detector is equal to or higher than the criterion value.

8. The refrigerant cycle system according to claim **7**, further comprising:

a first electric blower that blows exterior air to the heat-radiating heat exchanger; and

a first electric blower controller that controls a rotational speed of the first electric blower, wherein

the first electric blower controller raises the rotational speed of the first electric blower when the motor protection determiner determines that the temperature of the electric motor detected by the motor temperature detector is equal to or higher than the criterion value.

9. The refrigerant cycle system according to claim **6**, further comprising:

an evaporator that vaporizes the refrigerant decompressed by the variable throttle mechanism;

a second electric blower that blows heat-exchange target fluid to the evaporator; and

a second electric blower controller that controls a rotational speed of the second electric blower, wherein

the second electric blower controller lowers the rotational speed of the second electric blower when the motor protection determiner determines that the temperature of the electric motor detected by the motor temperature detector is equal to or higher than the criterion value.

10. The refrigerant cycle system according to claim **6**, further comprising:

an evaporator that vaporizes the refrigerant that is decompressed by the variable throttle mechanism; and

an interior/exterior air switcher that switches an air introducing mechanism between an interior air mode, in which air blown to the evaporator is introduced from an interior, and an exterior air mode, in which the air blown to the evaporator is introduced from an exterior, wherein

the interior/exterior air switcher switches the air introducing mechanism to the interior air mode when the motor protection determiner determines that the temperature of the electric motor detected by the motor temperature detector is equal to or higher than the criterion value.

11. The refrigerant cycle system according to claim **1**, wherein

the motor temperature detector includes a motor temperature detection sensor for detecting the temperature of the electric motor.

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