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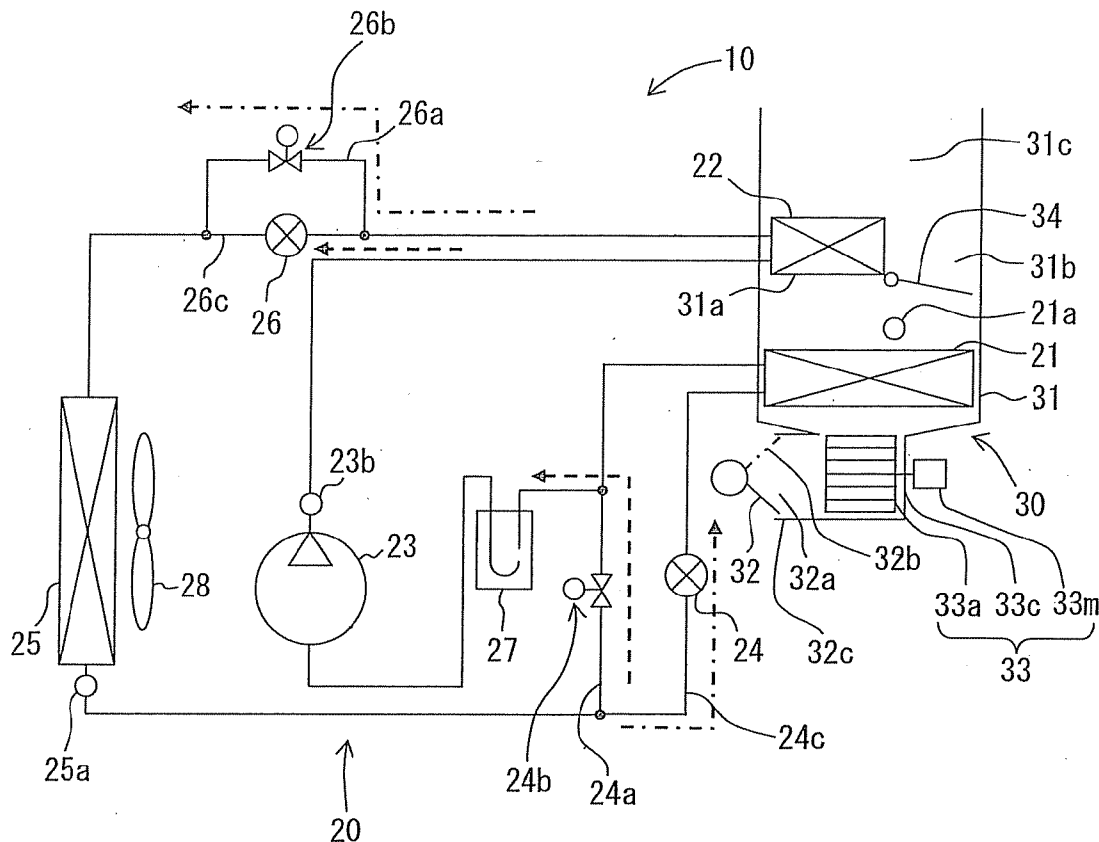


FIG. 1

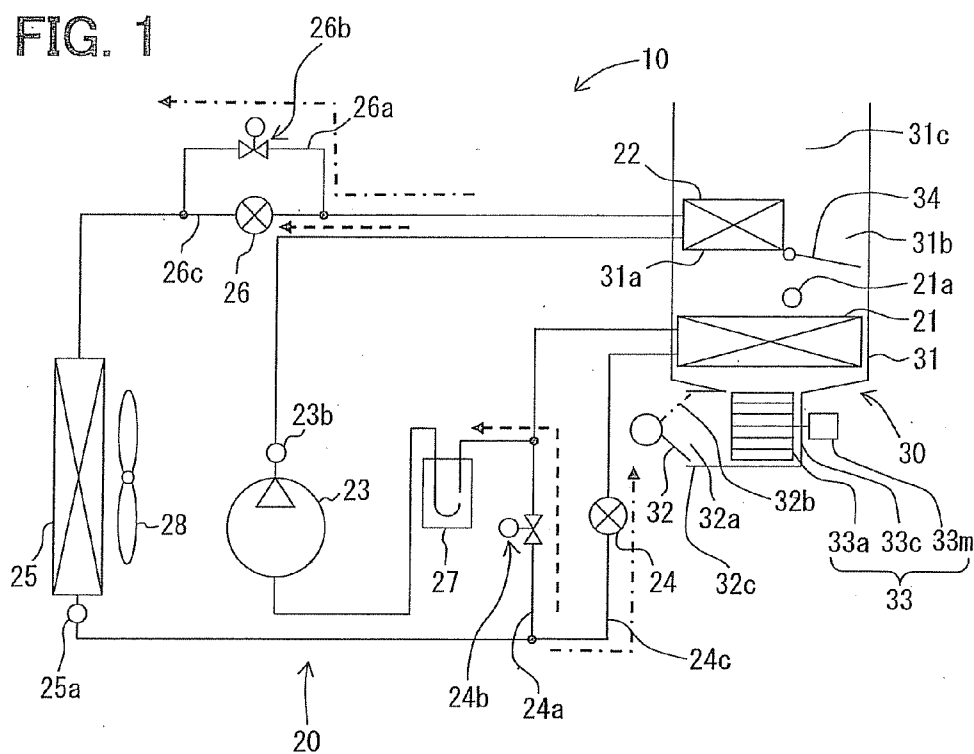


FIG. 2

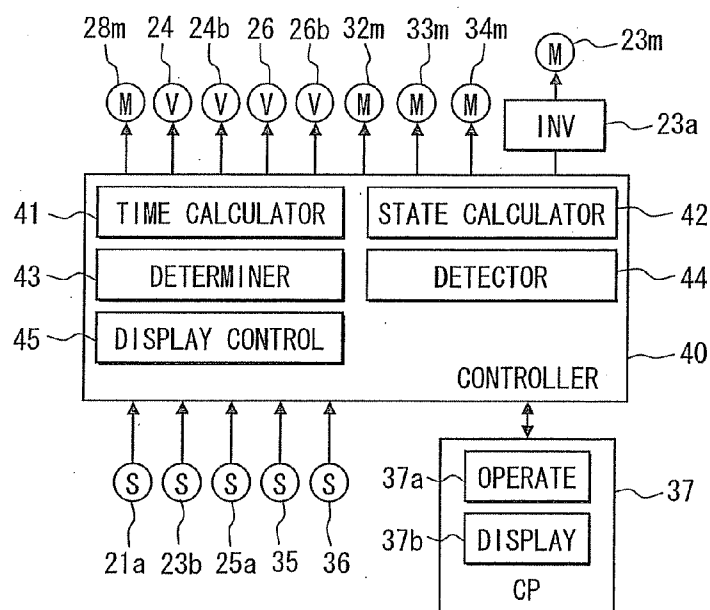


FIG. 3

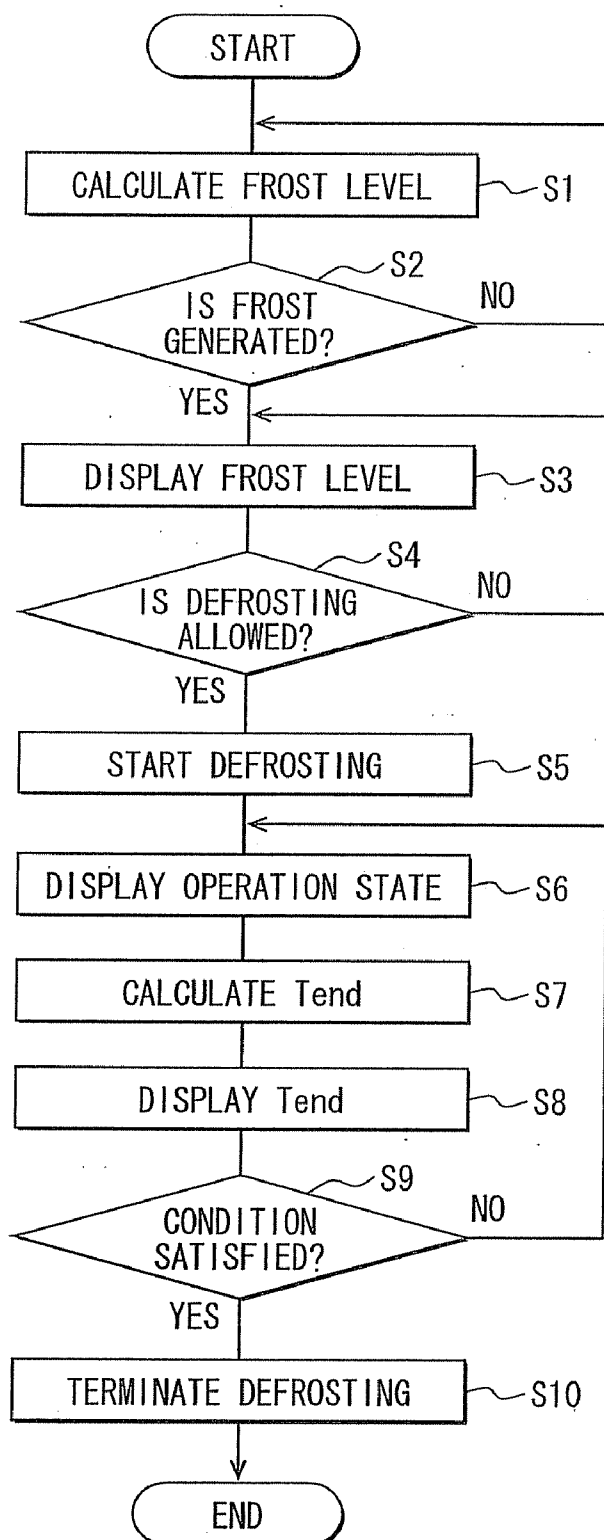


FIG. 4

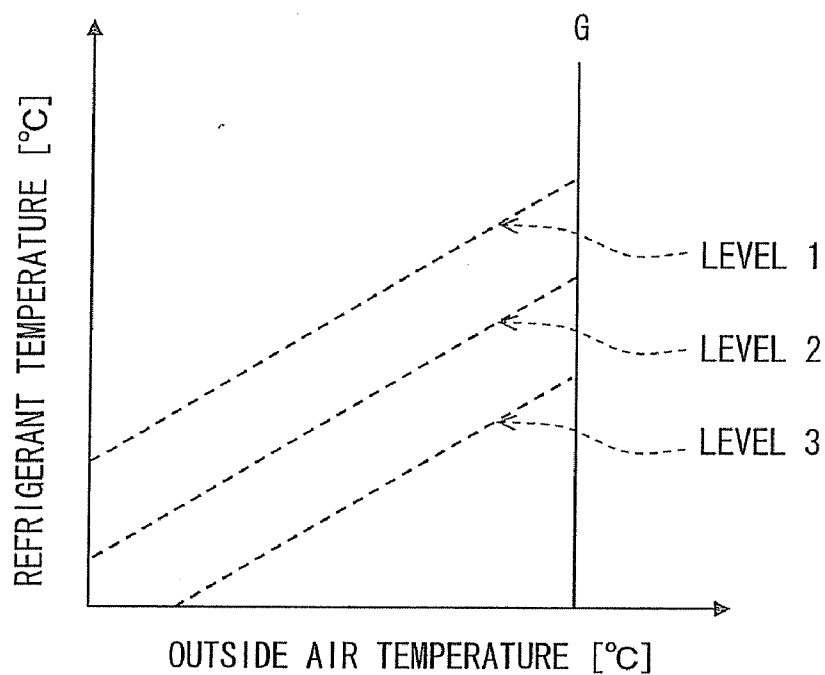


FIG. 5

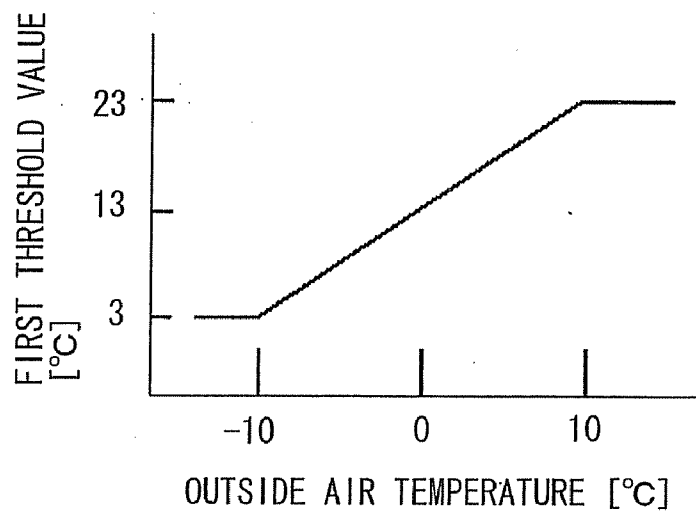


FIG. 6

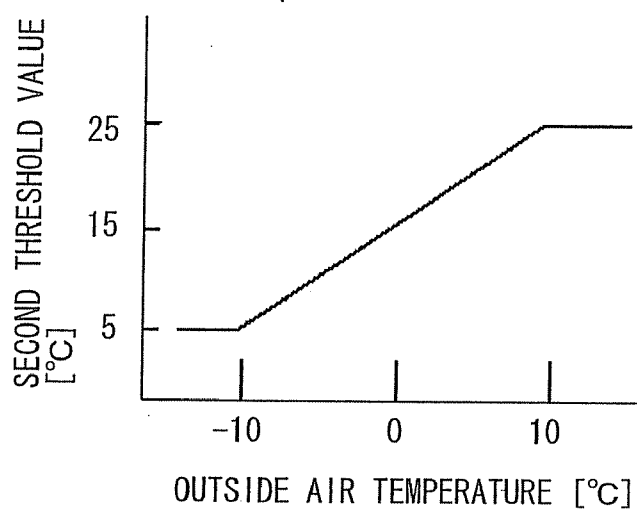


FIG. 7

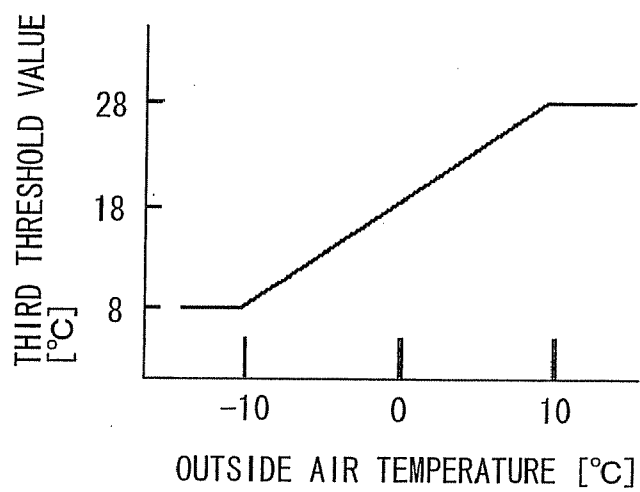


FIG. 8

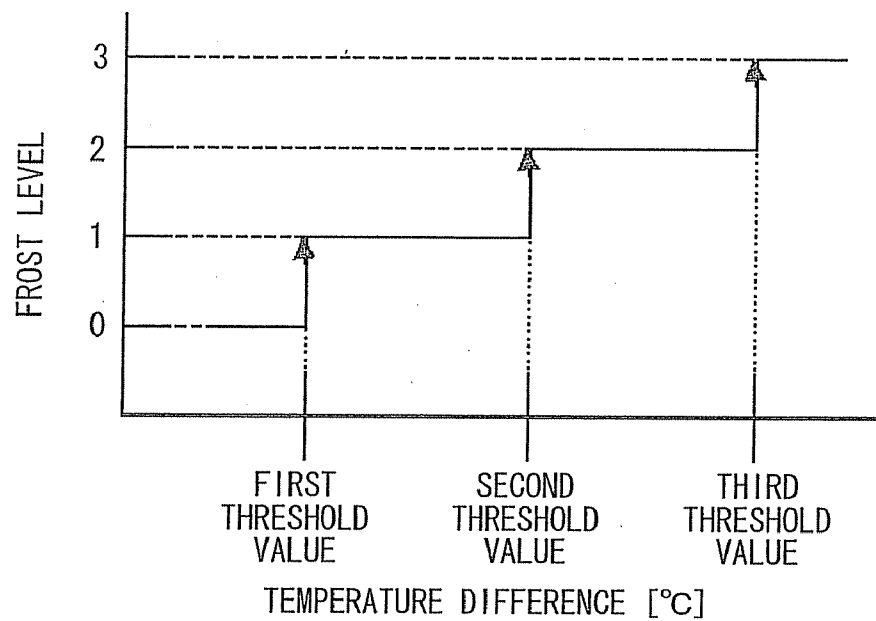


FIG. 9

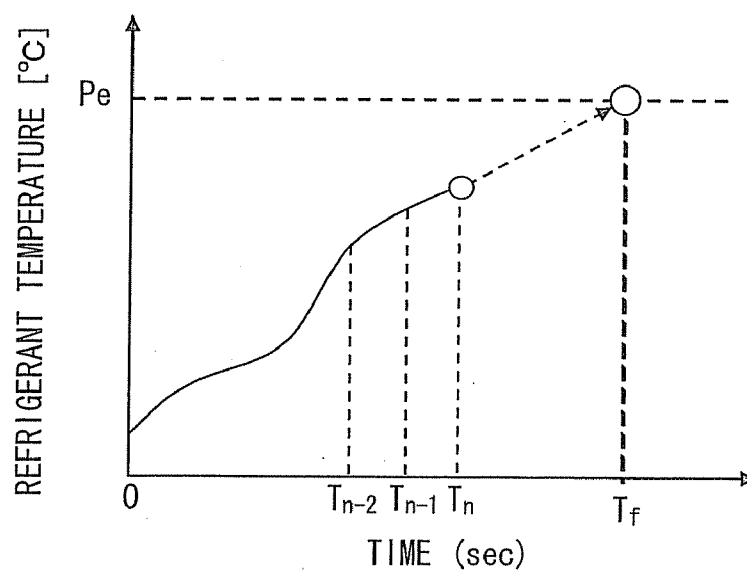


FIG. 10

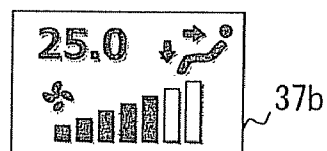


FIG. 11

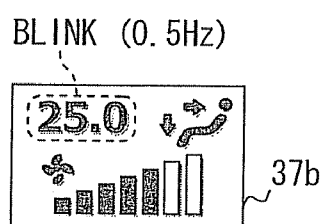


FIG. 12

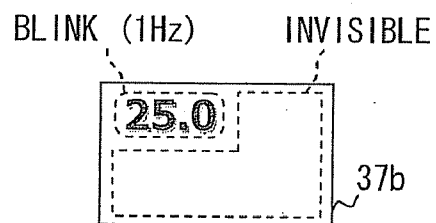
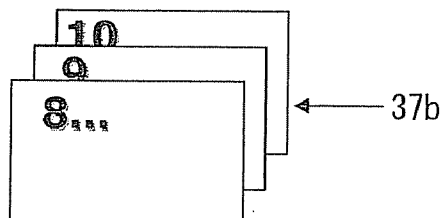


FIG. 13



AIR-CONDITIONER FOR VEHICLE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based on Japanese Patent Application No. 2011-50529 filed on Mar. 8, 2011, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to an air-conditioner for a vehicle.

BACKGROUND

[0003] An air-conditioner for a vehicle includes an outdoor heat exchanger in which refrigerant exchanges heat with outside air. When a temperature of the outside air is low, the outdoor heat exchanger may have frost. In this case, heat cannot be exchanged with the outside air, so that the heating capacity of the air-conditioner is lowered.

[0004] In JP-A-53-119449, a frost state of an outdoor heat exchanger is determined using a difference between a temperature of outside air and an evaporation temperature of refrigerant in the outdoor heat exchanger. If it is determined that the frost is generated, a defrosting operation is performed for defrosting the outdoor heat exchanger, and it is notified that the defrosting operation is being performed using a lamp, in JP-U-55-5002, for example.

[0005] However, it is not notified for an occupant of a vehicle when the defrosting operation is to be started. If the defrosting operation is started before the occupant is notified, the occupant may feel uncomfortable because the air-conditioning capacity is lowered while the defrosting operation is performed. Further, because air-conditioning cannot be performed while the defrosting operation is performed, fogging cannot be removed from a windshield of the vehicle during the defrosting operation.

SUMMARY

[0006] It is an object of the present disclosure to provide an air-conditioner for a vehicle.

[0007] According to an example of the present disclosure, an air-conditioner for a vehicle includes a heat pump cycle, a frost state calculator, an output portion and a controller. The heat pump cycle has an outdoor heat exchanger that condenses high-pressure refrigerant by exchanging heat with outside air. The frost state calculator calculates a degree of frost formed in the outdoor heat exchanger. The output portion outputs an information of the frost to an occupant of the vehicle. The controller performs a defrosting operation for melting the frost adhering to the outdoor heat exchanger by controlling a component of the heat pump cycle. The controller controls the output portion to output the degree of frost calculated by the frost state calculator as a frost information, when the defrosting operation is not being performed. The controller controls the output portion to output a defrosting information representing that the defrosting operation is being performed, when the defrosting operation is performed.

[0008] Accordingly, the occupant can know the frost information and the defrosting information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

[0010] FIG. 1 is a schematic view illustrating an air-conditioner according to an embodiment;

[0011] FIG. 2 is a block view illustrating a control configuration of the air-conditioner;

[0012] FIG. 3 is a flowchart illustrating a defrosting operation of the air-conditioner;

[0013] FIG. 4 is a graph illustrating a relationship between an outside air temperature and a refrigerant temperature in an outdoor heat exchanger of the air-conditioner;

[0014] FIG. 5 is a graph illustrating a relationship between the outside air temperature and a first threshold value;

[0015] FIG. 6 is a graph illustrating a relationship between the outside air temperature and a second threshold value;

[0016] FIG. 7 is a graph illustrating a relationship between the outside air temperature and a third threshold value;

[0017] FIG. 8 is a graph illustrating a relationship between a temperature difference between the outside air temperature and the refrigerant temperature and a frost level;

[0018] FIG. 9 is a graph illustrating a relationship between an elapsed time of the defrosting operation and the refrigerant temperature;

[0019] FIG. 10 is an image displayed in a normal operation of the air-conditioner;

[0020] FIG. 11 is an image displayed when frost is generated in the outdoor heat exchanger;

[0021] FIG. 12 is an image displayed in the defrosting operation; and

[0022] FIG. 13 is an image displayed in the defrosting operation to notify a remaining time period of the defrosting operation.

DETAILED DESCRIPTION

Embodiment

[0023] An air-conditioner 10 according to an embodiment has a heat pump cycle 20 and an air-conditioning unit 30, and performs air-conditioning for a hybrid vehicle, electric vehicle or fuel cell vehicle, for example. The air-conditioner 10 is configured to perform at least heating operation, cooling operation, and defrosting operation. The defrosting operation is performed for melting frost adhering to a heat exchanger by giving heat. The heat pump cycle 20 shown in FIG. 1 is an example that is applied to the air-conditioner 10. In the cycle 20, refrigerant flow has a heating cycle for the heating operation, or has a cooling-cycle for the cooling operation.

[0024] The heat pump cycle 20 performs the cooling operation or the heating operation for a passenger compartment of the vehicle by using state change of refrigerant flowing through the cycle. Specifically, the cooling operation is performed using an evaporator 21, and the heating operation is performed using an indoor heat exchanger 22. The refrigerant may be carbon dioxide whose pressure becomes equal to or higher than a super critical pressure.

[0025] As shown in FIG. 1, the heat pump cycle 20 has an electric compressor 23, the indoor heat exchanger 22, an electric valve 26, an outdoor heat exchanger 25, an electric

valve 24, the evaporator 21, and an accumulator 27, which are annually connected using a pipe so as to form the cycle.

[0026] The first electric valve 24 is arranged in a first branch passage 24c extending from the outdoor heat exchanger 25 to the evaporator 21, and a first bypass passage 24a extends to bypass the valve 24. A first electromagnetic valve 24b is arranged in the first bypass passage 24a, and has a parallel relationship with the first electric valve 24.

[0027] The second electric valve 26 is arranged in a second branch passage 26c extending from the indoor heat exchanger 22 to the outdoor heat exchanger 25, and a second bypass passage 26a extends to bypass the valve 26. A second electromagnetic valve 26b is arranged in the second bypass passage 26a, and has a parallel relationship with the second electric valve 26.

[0028] The first electric valve 24 is an expansion valve (decompressor) which decompresses refrigerant before flowing into the evaporator 21 at the time of cooling operation. For example, the valve 24 is an electronic control valve which can flexibly control the opening area of the refrigerant passage.

[0029] The first electromagnetic valve 24b opens or closes the first bypass passage 24a. The first bypass passage 24a is closed in the cooling operation, and is opened in the heating operation.

[0030] The refrigerant passage extending from the refrigerant outlet of the outdoor heat exchanger 25 is branched into the first branch passage 24c connected to the refrigerant inlet of the evaporator 21 and the first bypass passage 24a connected to the refrigerant inlet of the accumulator 27 by bypassing the evaporator 21.

[0031] The first branch passage 24c further extends from the refrigerant outlet of the evaporator 21, and is connected to the first bypass passage 24a adjacent to the refrigerant inlet of the accumulator 27. The first electric valve 24 is arranged in the first branch passage 24c on the inlet side of the evaporator 21. The first electromagnetic valve 24b is arranged in the first bypass passage 24a.

[0032] A refrigerant temperature sensor 25a is arranged on the outlet side of the outdoor heat exchanger 25. The refrigerant temperature sensor 25a is a refrigerant temperature detector detecting the refrigerant temperature in the outlet part of the outdoor heat exchanger 25.

[0033] The electric compressor 23 is driven by electricity supplied from an in-vehicle battery (not shown) which is a storage battery, and compresses refrigerant and discharges the high-temperature and high-pressure refrigerant. A rotation number of the compressor 23 is controllable.

[0034] Alternating-current (AC) voltage is applied to the compressor 23, and a frequency of the voltage is adjusted by an inverter 23a of FIG. 2. Thus, a rotation speed of an electric motor 23m of the compressor 23 is controlled. Direct-current (DC) power is supplied to the inverter 23a from the in-vehicle battery, and a controller 40 controls the inverter 23a.

[0035] The electric compressor 23 may be capacity variable compressor which can vary the compression capacity of refrigerant non-stepwise. The accumulator 27 is a tank in which the refrigerant is separated into vapor and liquid before the refrigerant flows into the electric compressor 23.

[0036] A discharge pressure sensor 23b is arranged at the refrigerant outlet of the compressor 23, and detects the pressure of refrigerant on the high-pressure side discharged from the compressor 23. A signal detected by the discharge pressure sensor 23b is input into the controller 40. Moreover, the

controller 40 computes a temperature of the high-pressure side refrigerant from the detected pressure in the cycle.

[0037] The refrigerant discharged from the compressor 23 flows into the indoor heat exchanger 22. Heat is exchanged between the high-pressure refrigerant and air flowing through a warm air passage 31a in the heating operation, so that the heat exchanger 22 heats the air.

[0038] The second electric valve 26 is an expansion valve (decompressor) which decompresses the refrigerant cooled by the indoor heat exchanger 22 at the time of heating operation. For example, the valve 26 may be an electronic control valve which flexibly controls the opening area of the refrigerant passage. The second electromagnetic valve 26b opens or closes the second bypass passage 26a. The second bypass passage 26a is closed in the heating operation, and is opened in the cooling operation.

[0039] The outdoor heat exchanger 25 is arranged out of the passenger compartment of the vehicle. Heat is exchanged between outside air compulsorily ventilated by an outdoor blower 28 and the refrigerant. In the heating operation, the refrigerant decompressed by the second electric valve 26 flows into the outdoor heat exchanger 25 and absorbs heat from the outside air. In the cooling operation, the high-pressure refrigerant emits heat to the outside air. The outdoor heat exchanger 25 condenses the refrigerant flowing out of the indoor heat exchanger 22 by exchanging heat with the outside air.

[0040] In the heating operation, the refrigerant does not flow the evaporator 21. In the cooling operation, the evaporator 21 cools the air to be sent into the passenger compartment because the refrigerant flowing through the evaporator 21 absorbs heat.

[0041] In the heating operation, the first electromagnetic valve 24b is opened, and the second electromagnetic valve 26b is closed. The first electric valve 24 is closed by 0-pulse control, and the second electric valve 26 is controlled to have a required decompress amount. Thereby, in the heating operation of the heat pump cycle 20, refrigerant flows in order of the accumulator 27, the compressor 23, the indoor heat exchanger 22, the second electric valve 26, the outdoor heat exchanger 25, the first electromagnetic valve 24b, and the accumulator 27 as shown in a broken line arrow direction in FIG. 1.

[0042] In the cooling operation, the first electromagnetic valve 24b is closed, and the second electromagnetic valve 26b is opened. The second electric valve 26 is closed by 0-pulse control, and the first electric valve 24 is controlled to have a required decompress amount. Thereby, in the cooling operation of the heat pump cycle 20, refrigerant flows in order of the accumulator 27, the compressor 23, the indoor heat exchanger 22, the second electromagnetic valve 26b, the outdoor heat exchanger 25, the first electric valve 24, the evaporator 21, and the accumulator 27 as shown in a single-chain line arrow direction of FIG. 1.

[0043] The air-conditioning unit 30 will be described. The unit 30 provides the conditioned air to the passenger compartment, and has a case 31 defining the outer shape of the unit 30. For example, the unit 30 is disposed on the back side of an instrument panel ahead of the passenger compartment. The case 31 defines an air passage inside. A first end of the passage has an inlet 32a for the outside air and an inlet 32b for the inside air. A second end of the passage has at least a face opening (not shown), foot opening (not shown), and defroster opening (not shown) through which the conditioned air flows

out into the passenger compartment. The case **31** is made of plural molded products made of resin such as polypropylene.

[0044] The conditioned air is blown off toward an upper body of the occupant in the passenger compartment through the face opening. The conditioned air is blown off toward a foot of the occupant in the passenger compartment through the foot opening. The conditioned air is blown off toward an inner face of a windshield of the vehicle through the defroster opening. Each opening is connected to the passenger compartment through a duct (not shown), and is opened/closed by a switching door (not shown) based on the air outlet mode.

[0045] The inside air inlet **32b** and the outside air inlet **32a** are opened or closed by a door **32** based on the air inlet mode, and the opening degree of the inlet **32b**, **32a** can be flexibly controlled by the door **32**. An angle of the door **32** is controlled by an actuator such as servo motor **32m**, and at least one of the outside air and the inside air is drawn into the case **31** through the inlet **32b**, **32a**. Thus, the air inlet mode is set among an inside air circulation mode, an outside air introduction mode, and a middle mode having both of the inside air circulation and the outside air introduction.

[0046] The case **31** has a switch box **32c** and a blower **33**. The door **32** is arranged in the box **32c**. An inlet part of the blower **33** is connected to the outside air inlet **32a** and the inside air inlet **32b**. In the heating operation, if the outside air introduction mode is selected, low-humidity outside air is introduced from the outside air inlet **32a**, and is blown to the inner face of the windshield after being conditioned in the passage, so that anti-fogging effect can be achieved. If the inside air circulation mode is selected, high-temperature inside air is introduced from the inside air inlet **32b**, and is blown to the foot of the occupant after being conditioned in the passage, so that the heating load can be reduced.

[0047] The blower **33** has a centrifugal multi-blade fan **33a** (for example, sirocco fan) and a motor **33m** which drives the fan **33a**. The circumference of the centrifugal fan **33a** is surrounded by a scroll casing **33c**. The air outlet of the blower **33** is connected to an air passage defined to extend in the centrifugal direction of the fan **33a**.

[0048] The air passage crosses the evaporator **21** on the upstream side in the air flowing direction. Further, the air passage has a cool air passage **31b** and the warm air passage **31a** downstream of the evaporator **21** in the air flowing direction. Furthermore, the air passage has a mix space **31c** in which air flowing from the cool air passage **31b** and air flowing from the warm air passage **31a** are mixed. The evaporator **21** is arranged downstream of the blower **33** in the case **31**, and the indoor heat exchanger **22** and an air mix door **34** are arranged downstream of the evaporator **21** in the case **31**.

[0049] The evaporator **21** is arranged to cross the entire passage immediately after the blower **33**. Almost all the air blown out from the blower **33** pass through the evaporator **21**. The evaporator **21** corresponds to a cooling heat exchanger that cools air before flowing through the cool air passage **31b** in the cooling operation and the defrosting operation, because refrigerant flowing inside of the evaporator **21** absorbs heat from the air. An evaporator temperature sensor **21a** is arranged at the outlet part of the evaporator **21** and detects the temperature of air cooled by the evaporator **21**. Signal detected by the temperature sensor **21a** is input into the controller **40**.

[0050] The indoor heat exchanger **22** is arranged in the warm air passage **31a**, and the warm air passage **31a** is opened or closed by the air mixing door **34**. The air mixing door **34** is

an air amount controller that controls the amount of the air (warm air) to pass the indoor heat exchanger **22** relative to the air drawn from the air inlet **32a**, **32b**. The air passing through the evaporator **21** is flexibly separated into air to pass the indoor heat exchanger **22** and air to bypass the indoor heat exchanger **22** by the air mixing door **34** at a predetermined ratio.

[0051] A servo motor **34m** of the door **34** closes a part or all of the passage **31a**, **31b** by changing a position of the door **34**. An open degree of the warm air passage **31a** is controlled in a range between 0% and 100% by the air mixing door **34**. The air enters the indoor heat exchanger **22** based on the open degree. Moreover, an open degree of the cool air passage **31b** is controlled by the air mixing door **34**, and changes in inverse proportion to the open degree of the warm air passage **31a**. The open degree of the cool air passage **31b** is controlled in a range between 0% and 100%.

[0052] The indoor heat exchanger **22** heats air flowing through the warm air passage **31a** in the heating operation, because refrigerant flowing inside of the heat exchanger **22** emits heat to the air. An outside air temperature sensor **35** detects a temperature of the outside air, and an inside air temperature sensor **36** detects a temperature of the inside air of the passenger compartment.

[0053] A control panel (CP) **37** is equipped with an operate part **37a** and a display part **37b**. The operate part **37a** is constructed by a touch-sensitive switch integrated with the display part **37b**, for example, or is made of a mechanical switch. Various instruction signals are input into the controller **40** through the operate part **37a**. The air outlet mode can be changed through the operate part **37a**, and the operation mode can be changed using the operate part **37a** among the heating operation, cooling operation and defrosting operation.

[0054] The operate part **37a** may be a starter, and the defrosting operation is started when an instruction is input to the operate part **37a** to start the defrosting operation. Moreover, the operate part **37a** may be a stopper, and the defrosting operation is stopped when an instruction is input to the operate part **37a** to stop the defrosting operation.

[0055] The display part **37b** is an output portion that outputs information about frost such as frost formation level to an occupant in the passenger compartment of the vehicle. Specifically, the display part **37b** lets the occupant know the information visually. The display part **37b** may be made of a liquid crystal display, for example. The display part **37b** displays various kinds of information provided from the controller **40** on a screen. For example, the display part **37b** displays the present air outlet mode and/or the present operation mode. Moreover, the display part **37b** displays information whether the defrosting operation is being performed or not, or information about time period taken for completing the defrosting operation (remaining time period of the defrosting operation).

[0056] The controller **40** of FIG. 2 is a control device that controls the air-conditioning operation and the defrosting operation to melt the frost of the outdoor heat exchanger **25**. The controller **40** controls each component constructing the heat pump cycle **20**, the outdoor blower **28**, the door **32**, the air mixing door **34** and the like based on the operational status.

[0057] The controller **40** includes a microcomputer (not shown), an input circuit (not shown), an output circuit (not shown), a defrosting time calculator **41**, a frost state calcula-

tor 42, a defrosting operation determiner 43, a drive state detector 44, and a display control 45.

[0058] Signal is input into the input circuit from the operate part 37a of the control panel 37 that is located on the front face of the passenger compartment. Further signal is input from the outside air temperature sensor 35, the refrigerant temperature sensor 25a, the discharge pressure sensor 23b, the evaporator temperature sensor 21a, and the inside air temperature sensor 36.

[0059] The microcomputer has a memory such as ROM (reading only memory) or RAM (reading and writing allowed memory) and a CPU (central processing unit), etc. The microcomputer has various programs for calculating the suitable operating state of each parts to be controlled. The microcomputer performs calculations using the various signals input into the input circuit and the various programs, and outputs a calculated result to the output circuit.

[0060] The output circuit sends an output signal to the inverter 23a, the first electric valve 24, the first electromagnetic valve 24b, the second electric valve 26, the second electromagnetic valve 26b, the motor 28m of the outdoor blower 28, the motor 32m of the door 32, the motor 33m of the blower 33, and the motor 34m of the air mixing door 34, and the display part 37b of the control panel 37 based on the calculated result.

[0061] The frost state calculator 42 computes the frost formation degree (level) using the outside air temperature and the refrigerant temperature of the outdoor heat exchanger 25, and transmits the frost formation level to the microcomputer. The frost formation degree represents an amount of frost formed in the outdoor heat exchanger 25.

[0062] The defrosting operation determiner 43 determines whether the defrosting operation is required or not based on the frost formation level, and the determination result is transmitted to the microcomputer.

[0063] The defrosting time calculator 41 calculates a time period taken for ending the defrosting operation using the frost formation level during the defrosting operation. The calculated time period is transmitted to the microcomputer.

[0064] The display control 45 controls an image displayed on the display part 37b. The display control 45 produces a predetermined image based on the information provided from the microcomputer. Further, the display control 45 controls the timing and the position for displaying the image.

[0065] The drive state detector 44 detects the drive state of the vehicle by detecting the speed of the vehicle and the switching status of an ignition switch (not shown), for example. In addition, the drive state detector 44 may be included in the variety of sensors that provide the information to the controller 40. The information detected by the detector 44 is transmitted to the microcomputer. The switching status of the ignition switch represents on/off of the ignition switch of the vehicle.

[0066] The operation (cooling, heating and defrosting) of the air-conditioner 10 will be described. When an air-conditioning (A/C) switch of the operate part 37a of the control panel 37 is turned on, the controller 40 activates the compressor 23. If the controller 40 determines that the cooling operation is required based on a temperature set by the occupant of the vehicle and the signals received from the variety of sensors, the second electromagnetic valve 26b is opened, and the first electromagnetic valve 24b and the second electric valve 26 are closed. Further, the controller 40 controls the opening degree of the first electric valve 24 to have a decompressing

amount so as to obtain a required cooling ability. Furthermore, the controller 40 controls the air outlet switching door in a manner that the air outlet mode is set into the face mode for the cooling operation.

[0067] In the cooling operation, refrigerant flows in the single-chained arrow direction of FIG. 1. While the gas refrigerant having high-temperature and high-pressure discharged from the compressor 23 flows into the indoor heat exchanger 22, there is no air passing through the indoor heat exchanger 22, so that the amount of heat emitted from the refrigerant in the indoor heat exchanger 22 is small.

[0068] The refrigerant flows into the outdoor heat exchanger 25 through the second bypass passage 26a. When the refrigerant passes the outdoor heat exchanger 25, air sent by the outdoor blower 28 cools the refrigerant by absorbing heat, so that the refrigerant comes to have the mist state. The mist state refrigerant flows through the passage 24c, and is decompressed by the first valve 24. The decompressed refrigerant flows into the evaporator 21, and is evaporated by absorbing heat from air flowing through the air passage of the case 31. The refrigerant is divided into gas and liquid in the accumulator 27, and is drawn to the compressor 23. The air cooled by the evaporator 21 is blown out toward the upper body of the occupant through the face outlet so as to cool the passenger compartment.

[0069] The refrigerant flow will be described in case where the heating operation is performed. When the air-conditioning (A/C) switch of the operate part 37a of the control panel 37 is turned on, the controller 40 activates the compressor 23. If the controller 40 determines that the heating operation is required based on a temperature set by the occupant of the vehicle and the signals received from the variety of sensors, the first electromagnetic valve 24b is opened, and the second electromagnetic valve 26b and the first electric valve 24 are closed. Further, the controller 40 controls the opening degree of the second electric valve 26 to have a decompressing amount. Furthermore, the controller 40 controls the air outlet switching door in a manner that the air outlet mode is set into the foot mode or the defroster mode based on the preset temperature for the heating operation.

[0070] In the heating operation, refrigerant flows in the broken-line arrow direction of FIG. 1. While the gas refrigerant having high-temperature and high-pressure discharged from the compressor 23 flows into the indoor heat exchanger 22, heat of the refrigerant is absorbed by air passing through the warm air passage 31a so as to cool the refrigerant. The refrigerant flows into the passage 26c and is decompressed by the second electric valve 26. The decompressed refrigerant flows into the outdoor heat exchanger 25. When the refrigerant passes the outdoor heat exchanger 25, the refrigerant absorbs heat from air sent by the outdoor blower 28, so that the refrigerant is evaporated. The evaporated gas refrigerant flows through the passage 24a and the first electromagnetic valve 24b. The refrigerant is divided into gas and liquid in the accumulator 27, and is drawn to the compressor 23.

[0071] In the heating operation, low-temperature air (for example, outside air in winter season) drawn into the case 31 passes the evaporator 21, and the air mix door 34 causes the air to flow through the warm air passage 31a. The air is heated by the indoor heat exchanger 22 so as to be warmed. In a case where the defroster mode is selected in the heating operation, the warmed air passes the indoor heat exchanger 22 and is blown out toward the inner face of the windshield through the defroster opening. Further, in a case where the foot mode is

selected in the heating operation, the warmed air passes the indoor heat exchanger 22 and is blown out toward the foot of the occupant through the foot opening.

[0072] In a case where a bi-level mode is selected in the heating operation, the air mix door 34 divides low-temperature air drawn into the case 31 between the cool air passage 31b and the warm air passage 31a at an appropriate ratio. Low-temperature air flowing through the warm air passage 31a is heated by the indoor heat exchanger 22, and is mixed with low-temperature air flowing through the cool air passage 31b in the mix space 31c. The temperature-controlled warmed air is blown out toward the foot of the occupant through the foot opening.

[0073] Low-temperature air flowing through the cool air passage 31b is not heated, and is mixed in the mix space 31c with the air warmed in the warm air passage 31a. The temperature-controlled cool air is blown out toward the upper body of the occupant through the face opening. Thus, the conditioned air is blown out to each of the upper body and the foot of the occupant, and the warm air blown to the foot and the cool air blown to the upper body has an appropriate temperature difference such as 10-15° C. Accordingly, the conditioned airs heat the foot of the occupant and cool the upper body (around the head) of the occupant, respectively.

[0074] The defrosting operation will be described. The defrosting operation has a first mode and a second mode, and one mode is selected between the first mode and the second mode by the occupant.

[0075] The first mode will be described. In the first mode, the heat pump cycle 20 is operated so as to have the same refrigerant flow as the heating operation. Further, the controller 40 stops the outdoor blower 28 and sets the outside air introduction mode. The speed of the blower 33 is lowered so as to reduce the air sending amount, and the opening of the air mix door 34 is controlled so as to obtain a predetermined heating ability.

[0076] Thereby, the refrigerant in the heat pump cycle 20 emits heat in the indoor heat exchanger 22 by exchanging heat with air flowing through the warm air passage 31a so as to provide the warmed air. In contrast, because the outdoor blower 28 is stopped, heat exchange between the refrigerant and the outside air is not so much performed in the outdoor heat exchanger 25. The surface of the outdoor heat exchanger 25 is warmed by the heat of refrigerant so as to melt the frost adhering to the outdoor heat exchanger 25. At this time, the power of the compressor 23 is used for the heat emission in the indoor heat exchanger 22 and for the heat emission in the outdoor heat exchanger 25. Therefore, in the first mode of the defrosting operation, the frost of the outdoor heat exchanger 25 can be removed while the heating operation is performed at the same time.

[0077] The second mode will be described. In the second mode, the heat pump cycle 20 is operated so as to have the same refrigerant flow as the cooling operation. Further, the controller 40 stops the outdoor blower 28 and sets the inside air circulation mode or the middle mode that has both of the inside air circulation mode and the outside air introduction mode. The speed of the blower 33 is raised so as to increase the air sending amount, and the opening of the air mix door 34 is reduced so as to throttle the warm air passage 31a.

[0078] Thereby, the refrigerant in the heat pump cycle 20 does not emit heat in the indoor heat exchanger 22 because heat exchange between the refrigerant and the air is not so much performed. Further, because the outdoor blower 28 is

stopped, heat exchange between the refrigerant and the outside air is not so much performed in the outdoor heat exchanger 25. The surface of the outdoor heat exchanger 25 is warmed by the heat of refrigerant so as to melt the frost adhering to the outdoor heat exchanger 25.

[0079] Further, heat is exchanged in the evaporator 21 between the refrigerant decompressed by the first electric valve 24 and the inside air sent by the blower 33, so that the refrigerant absorbs heat from the inside air. At this time, the heat pump cycle 20 works as a normal super critical cycle. Therefore, in the defrosting operation, the inside air is heated by waste heat of the vehicle, and the amount of the heated air drawn into the case 31 is increased, so that the evaporator 21 can efficiently perform heat recovery by absorbing heat from the inside air.

[0080] Operation of the air-conditioner 10 will be described with reference to FIG. 3. The flow chart of FIG. 3 represents a processing performed by the controller 40, and is executed when the ignition switch of the vehicle is turned on.

[0081] When the processing is started, the frost formation level is calculated at S1 by the frost state calculator 42 based on a difference between the outside air temperature and the refrigerant temperature in the outdoor heat exchanger 25.

[0082] At S2, it is determined whether the frost is generated or not based on the frost formation level calculated at S1. If the frost is determined not to be generated at S2, the processing is returned to S1. If the frost is determined to be generated at S2, frost information representing the frost level is displayed by the display part 37b at S3. For example, when the maximum-level frost is generated, information indicating that the frost is generated at the maximum level is displayed as a defrosting-required information.

[0083] At S4, it is determined whether the defrosting operation is allowed or not. If the defrosting operation is not allowed, the processing is returned to S3. If the defrosting operation is allowed, the processing is advanced to S5. For example, when the frost level is determined to reach the maximum level by the determiner 43, the defrosting operation is automatically allowed, in an automatic defrosting mode. In this case, the defrosting operation is allowed. Further, if the occupant inputs an instruction to the operate part 37a so as to start the defrosting operation, the defrosting operation is allowed. Furthermore, if frost is generated while a pre-air-conditioning is performed for the passenger compartment, the defrosting operation is allowed.

[0084] At S5, the controller 40 controls the air-conditioner 10 to start the defrosting operation. At S6, the display part 37b is controlled to display information representing that the defrosting is being performed. The information further includes information of the frost level. Therefore, the occupant can know that the defrosting operation is being performed and a change in the frost level caused by the defrosting operation.

[0085] At S7, the time calculator 41 calculates a remaining time period of the defrosting operation (Tend), that is, a time period necessary for completing the defrosting operation. At S8, the controller 40 controls the display part 37b to display the calculated remaining time period of the defrosting operation.

[0086] At S9, the determiner 43 determines whether a condition for finishing the defrosting operation is satisfied or not. If the condition is not satisfied, the processing is returned to S6, and the defrosting operation is continued. If the condition is satisfied, the processing is advanced to S10. For example,

when the frost level is lowered to a predetermined level, the condition is regarded to be satisfied. Alternatively, when the occupant operates the operate part 37a so as to stop the defrosting operation, the condition is regarded to be satisfied. Alternatively, when the drive state detector 44 detects the vehicle to start driving, the condition is regarded to be satisfied. The determination may be performed by further referring to other condition such as outside air temperature. At S10, each component of the heat pump cycle 10 is instructed to stop the defrosting operation, and the processing is terminated.

[0087] Thus, before the defrosting operation is started, the frost formation level is displayed at S3. During the defrosting operation, the operation state of the defrosting operation is displayed at S6 and the remaining time period of the defrosting operation is displayed at S8. Accordingly, the occupant can determine to start/stop the defrosting operation based on the information displayed on the display part 37b.

[0088] The calculation of the frost level at S1 will be specifically described with reference to FIGS. 4-8. FIG. 4 is a graph illustrating an example relationship between the present outside air temperature and the temperature of refrigerant at the outlet part of the outdoor heat exchanger 25. A horizontal axis of FIG. 4 represents the outside air temperature, and a vertical axis of FIG. 4 represents the refrigerant temperature. A dashed line of FIG. 4 represents a change in the evaporation temperature of the outdoor heat exchanger 25, and is changed by the condition of the outside air temperature. A vertical line G of FIG. 4 represents a critical limit of the defrosting operation. If the outside air temperature becomes equal to or higher than a threshold value such as 12° C., the defrosting operation is prohibited regardless of the refrigerant temperature of the outdoor heat exchanger 25.

[0089] When the refrigerant temperature becomes lower than a temperature represented by the dashed line of level 1, it is determined that the frost is generated. The advancing state of the frost is determined as a level by defining the dashed line of level 2 and the dashed line of level 3. The amount of the frost is increased in order of the level 1, the level 2 and the level 3. When the outside air temperature is the same, as the refrigerant temperature is decreased, the temperature difference between the outside air temperature and the refrigerant temperature becomes large, so that the amount of the frost is increased. The frost level is calculated using the model shown in FIG. 4.

[0090] A specific method of calculating the frost level will be described with reference to FIGS. 5-8. The frost level is changed by the temperature difference between the outside air temperature and the refrigerant temperature, as shown in FIG. 4. Three threshold values are set for defining the frost level relative to the outside air temperature, and correspond to the dashed lines of FIG. 4, respectively. For example, when the outside air temperature is -10° C., the first threshold value is set as 3° C. in FIG. 5, the second threshold value is set as 5° C. in FIG. 6, and the third threshold value is set as 8° C. in FIG. 7.

[0091] The frost level is determined using the threshold values and the temperature difference, as shown in FIG. 8.

[0092] When the temperature difference is smaller than the first threshold value, the frost level is defined as level 0. When the temperature difference is equal to or larger than the first threshold value and is smaller than the second threshold value, the frost level is defined as level 1. When the temperature difference is equal to or larger than the second threshold

value and is smaller than the third threshold value, the frost level is defined as level 2. When the temperature difference is equal to or larger than the third threshold value, the frost level is defined as level 3.

[0093] For example, in a case where the outside air temperature is -10° C., when the temperature difference is equal to or larger than 3° C. and is smaller than 5° C., the frost level is defined as level 1. When the temperature difference is equal to or larger than 5° C. and is smaller than 8° C., the frost level is defined as level 2. When the temperature difference is equal to or larger than 8° C., the frost level is defined as level 3.

[0094] Thus, the frost state calculator 42 determines the frost level based on the outside air temperature and the temperature difference between the outside air temperature and the refrigerant temperature. The frost level is not limited to have three levels. The frost level may have two levels or four or more levels.

[0095] The calculation of the remaining time period of the defrosting operation at S7 will be described with reference to FIG. 9. FIG. 9 is a graph illustrating an example relationship between an elapsed time of the defrosting operation and the refrigerant temperature. A horizontal axis of FIG. 9 represents the elapsed time of the defrosting operation, and the defrosting operation is defined to start at time of 0.

[0096] The refrigerant temperature has a predetermined value P_e for completing the defrosting operation (e.g., 5° C.) as the condition for finishing the defrosting operation. When the refrigerant temperature exceeds the predetermined temperature P_e due to the defrosting operation, the defrosting operation is finished.

[0097] As shown in FIG. 9, the time calculator 41 calculates a time period taken from the present time T_n to the finish time of the defrosting operation T_f . The calculated time period ($T_f - T_n$) corresponds to the remaining time period of the defrosting operation (T_{end}).

[0098] Specifically, when time period ΔT is elapsed from T_{n-2} to T_{n-1} or from T_{n-1} to T_n , the refrigerant temperature is varied (increased in FIG. 9). A gradient is calculated by dividing the variation of the refrigerant temperature by the time period ΔT , and an average of the gradients is calculated using n-samples (e.g., $n=4$ and $\Delta T=0.25$ sec). The remaining time period of the defrosting operation T_{end} is calculated based on the present time T_n , the average of the gradients and the predetermined temperature P_e .

[0099] Examples of the image displayed by the display part 37b will be described with reference to FIGS. 10-13. FIG. 10 illustrates an image displayed at a normal operation time. As shown in FIG. 10, information relating to the preset temperature, the air amount, and the air outlet mode is displayed during the heating operation or the cooling operation.

[0100] FIG. 11 illustrates an image displayed when frost is generated. As shown in FIG. 11, the preset temperature is displayed in blink state having a frequency of 0.5 Hz, for example, at the frost generated time. The image of FIG. 11 is an example of the image displayed at S3. The speed of the blinking or the color of the display part 37b may be changed in accordance with the frost level. Further, other image may be displayed in other display area in accordance with the frost level. The frost level may be indicated by the number of the other images.

[0101] FIG. 12 illustrates an image displayed when the defrosting operation is being performed. As shown in FIG. 12, the image other than the preset temperature is made invisible, and the present temperature is displayed in blink state

having a frequency of 1 Hz during the defrosting operation, for example. The blinking speed in the defrosting operation is faster than that in the frost generated time. The image of FIG. 12 is an example of the image displayed at S6. Further, information clarifying that the defrosting operation is being performed may be displayed in the invisible area. Furthermore, an original mark that indicating that the defrosting operation is being performed may be displayed.

[0102] FIG. 13 illustrates an image indicating the remaining time period of the defrosting operation. In FIG. 13, three images are partially overlap with time elapsing so as to imaginarily display an image. As shown in FIG. 13, the remaining time period of the defrosting operation is displayed in the display area of the preset temperature, and the other image is made invisible. The image of FIG. 13 is an example of the image displayed at S8. Further, information clarifying that the count down of the remaining time period is being performed may be displayed in the invisible area. Furthermore, an end time of the defrosting operation may be calculated by adding the remaining time period to the present time, and the calculated end time of the defrosting operation may be displayed.

[0103] According to the embodiment, when the defrosting operation is not performed, the controller 40 controls the display part 37b to output the frost information representing the frost formation degree or level, as shown in S3 of FIG. 3. Therefore, the occupant can recognize the frost degree from the information. The occupant can predict that the start timing of the defrosting operation to some extent from the frost degree by the recognition. Thus, the occupant is restricted from feeling that the defrosting operation is suddenly started even if the defrosting operation is automatically started in response to the frost state.

[0104] While the defrosting operation is being performed, the controller 40 controls the display part 37b to output the defrosting information representing the defrosting operation is being performed, as shown in S6 of FIG. 3. Therefore, the occupant can recognize that the defrosting operation is being performed. Thus, the occupant can know that a lowering in the air-conditioning ability is caused by the defrosting operation. The information about the defrosting operation can improve the convenience of the occupant.

[0105] While the defrosting operation is being performed, the controller 40 controls the display part 37b to output the information that the defrosting operation is being performed and the remaining time period of the defrosting operation, as shown in S8 of FIG. 3. Therefore, the occupant can recognize the time period necessary for finishing the defrosting operation. Thus, even if the air-conditioning ability is lowered by the defrosting operation, the occupant can know that the air-conditioning ability is recovered after the time period is elapsed.

[0106] In a case where the defrosting operation is not performed, if the determiner 43 determines that the defrosting operation is necessary, the controller 40 controls the display part 37b to output information representing that the defrosting operation is necessary, as shown in S3 of FIG. 3. Therefore, the occupant can recognize that the defrosting operation is necessary. Thus, the occupant can know that a lowering in the air-conditioning ability is caused by the frost.

[0107] When the information instructing the start of the defrosting operation is input into the operate part 37a corresponding to a starter, the controller 40 controls each component to conduct the defrosting operation, as shown in S4 of FIG. 3. Therefore, the occupant can start the defrosting opera-

tion at a suitable timing determined by the occupant based on the frost degree. Even if the frost degree is low, the defrosting operation can be instructed by the occupant, so as to prevent the frost amount from becoming large.

[0108] When the information instructing the stop of the defrosting operation is input into the operate part 37a corresponding to a stopper, the controller 40 controls each component to stop the defrosting operation, as shown in S9 of FIG. 3. Therefore, the occupant can stop the defrosting operation at a suitable timing determined by the occupant. Although the defrosting operation is not completed, if the frost degree becomes low, the defrosting operation can be stopped by the occupant. In this case, air-conditioning can be performed for the passenger compartment with the air-conditioning ability which is recovered to some extent.

[0109] While the defrosting operation is conducted in the state where the vehicle is stopped, if the drive state detector 44 detects the start of the drive of the vehicle, the controller 40 controls each component to stop the defrosting operation, as shown in S9 of FIG. 3. Therefore, when the vehicle starts to drive, the defrosting operation is automatically stopped. Thus, the air-conditioning ability can be restricted from being lowered by the defrosting operation when the vehicle starts to drive.

[0110] The frost state detector 42 detects the frost degree using the temperature difference between the outside air temperature and the refrigerant temperature. Therefore, the detector 42 can accurately detect the frost degree without being affected by disturbance.

[0111] Because the driver of the vehicle can know the operational status of the air-conditioner 10, the driver can know that the lowering in the air-conditioning ability is caused by the frost not by the break down. Further, the driver can know the state of the frost visually. The defrosting operation can be started by the driver (user), and the driver can see the time period necessary for finishing the defrosting operation. For example, the defrosting operation can be performed using a short time during which the vehicle stops until a traffic signal is changed from red to green at the convenient timing. Because the time period necessary for finishing the defrosting operation can be seen, the occupant can be made to wait the elapsing of the time period. As a result, the defrosting can be suitably achieved for the outdoor heat exchanger.

[0112] The preferred embodiment is described above. However, the present disclosure is not limited to the above embodiment.

[0113] The frost information representing the frost degree has three frost levels. Alternatively, the frost information may represent the amount of the frost. Further, the frost information may have four or more levels for the frost.

[0114] The frost state calculator is not limited to use the outside air temperature and the refrigerant temperature. Alternatively, a humidity sensor may be arranged to the outdoor heat exchanger. In this case, the frost state can be more accurately detected by using the information provided by the humidity sensor.

[0115] The image displayed on the display part 37b is just example, and is not limited to the above example. Further, the output portion is not limited to the display part 37b, and the other device may be used as the output portion. Actual operation state such as cooling, heating, dehumidifying or defrosting may be displayed on the display part 37b as the operation state. The remaining time period of the defrosting operation may be displayed by original (exclusive) liquid crystal por-

tion or the other method. The information may be output from the output portion through light, voice or vibration other than the image.

[0116] Such changes and modifications are to be understood as being within the scope of the present disclosure as defined by the appended claims.

What is claimed is:

1. An air-conditioner for a vehicle comprising:
 - a heat pump cycle having an outdoor heat exchanger that condenses high-pressure refrigerant by exchanging heat with outside air;
 - a frost state calculator that calculates a degree of frost formed in the outdoor heat exchanger;
 - an output portion that outputs information of the frost formed in the outdoor heat exchanger; and
 - a controller that instructs a defrosting operation for melting the frost adhering to the outdoor heat exchanger by controlling a component of the heat pump cycle, wherein
 - the controller controls the output portion to output the degree of frost calculated by the frost state calculator as a frost information, when the defrosting operation is not performed, and
 - the controller controls the output portion to output a defrosting information representing that the defrosting operation is being performed, when the defrosting operation is performed.
2. The air-conditioner according to claim 1, wherein
 - the controller calculates a remaining time period of the defrosting operation taken for finishing the defrosting operation based on the degree of frost while the defrosting operation is performed, and
 - the controller controls the output portion to output the defrosting information and the remaining time period of the defrosting operation while the defrosting operation is performed.
3. The air-conditioner according to claim 1, further comprising:
 - a determiner that determines whether the degree of frost requires the defrosting operation, wherein
 - the controller controls the output portion to output a requirement information representing that the defrost-

ing operation is necessary when the determiner determines that the defrosting operation is necessary while the defrosting operation is not performed.

4. The air-conditioner according to claim 1, further comprising:

- a starter that inputs a start information representing that the defrosting operation is to be started to the controller, wherein

- the controller controls the component of the heat pump cycle to start the defrosting operation when the starter inputs the start information to the controller.

5. The air-conditioner according to claim 1, further comprising:

- a stopper that inputs a stop information representing that the defrosting operation is to be stopped to the controller, wherein

- the controller controls the component of the heat pump cycle to stop the defrosting operation when the stopper inputs the stop information to the controller.

6. The air-conditioner according to claim 1, further comprising:

- a drive state detector that detects a driving state of the vehicle, wherein

- the controller controls the component of the heat pump cycle to stop the defrosting operation when the detector detects the vehicle to start driving while the defrosting operation is performed in a state where the vehicle is stopped.

7. The air-conditioner according to claim 1, further comprising:

- a first temperature detector that detects a temperature of the outside air; and

- a second temperature detector that detects a temperature of the refrigerant at a refrigerant outlet part of the outdoor heat exchanger, wherein

- the frost state calculator calculates the degree of frost using a difference between the detected temperature of the outside air and the detected temperature of the refrigerant.

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