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(54) AIR CONDITIONER FOR VEHICLE

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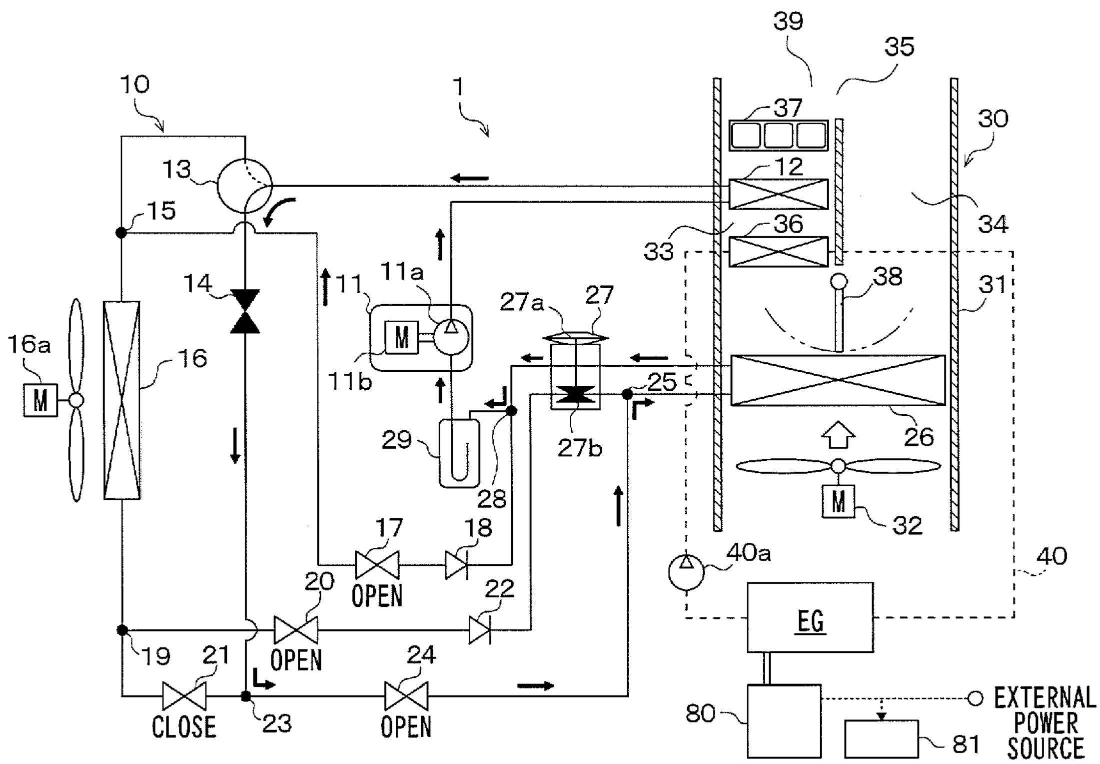
USPC **165/204**; 165/41

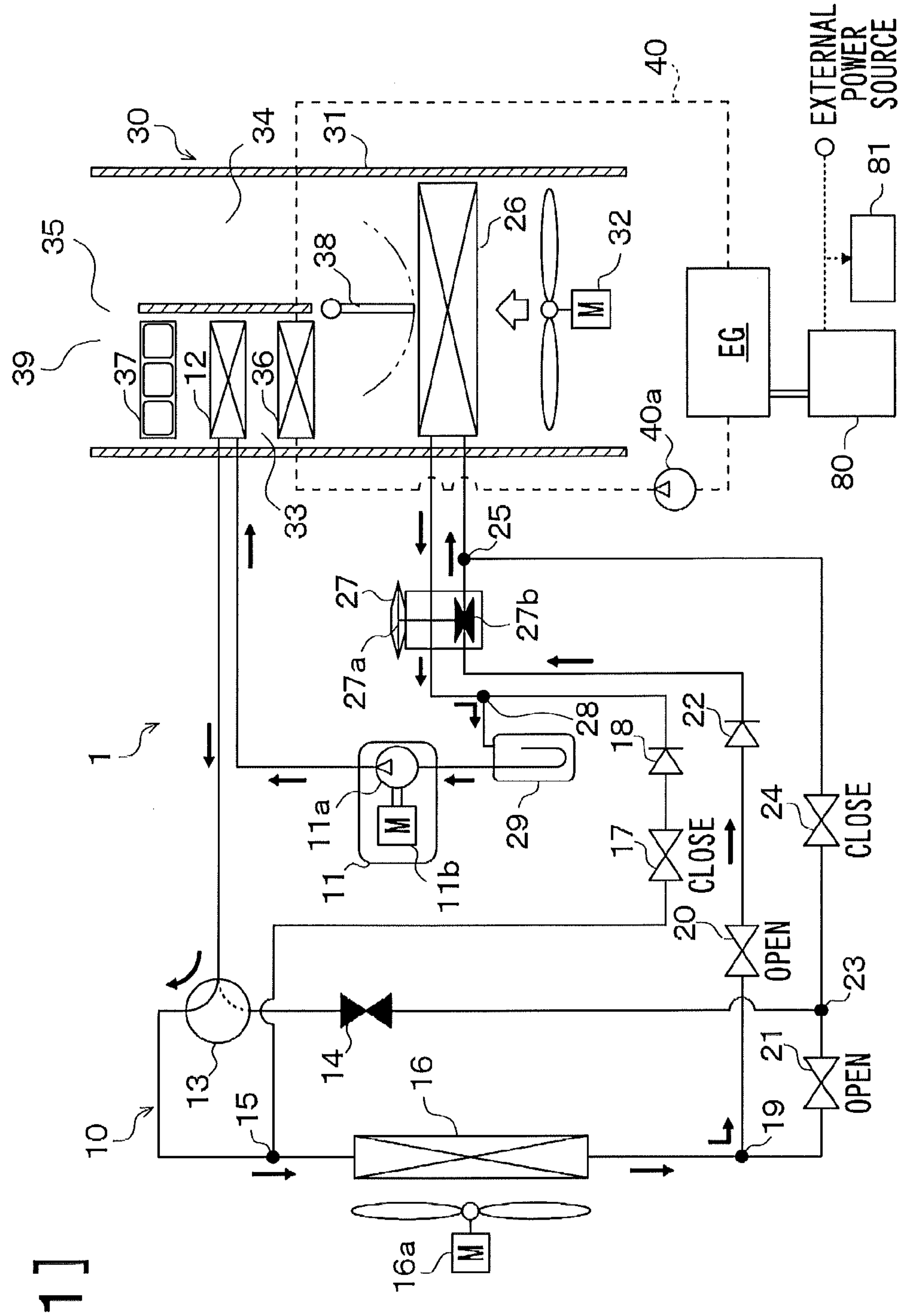
(57) **ABSTRACT**

An air conditioner for a vehicle includes a blower; a heat exchanger that heats the blown air by heat exchanger between blown air and a heat medium, a control device, and an air outlet mode switching device that switches between air outlet modes by switching proportions of air flow blown out from outlets which includes a face air outlet and a foot air outlet, wherein the control device limits the availability factor of the blower based on a temperature of the heat medium; and relaxes limitation on the availability factor of the blower when the air outlet mode is a bi-level mode in which the blown air is blown out from both of the face air outlet and the foot air outlet.



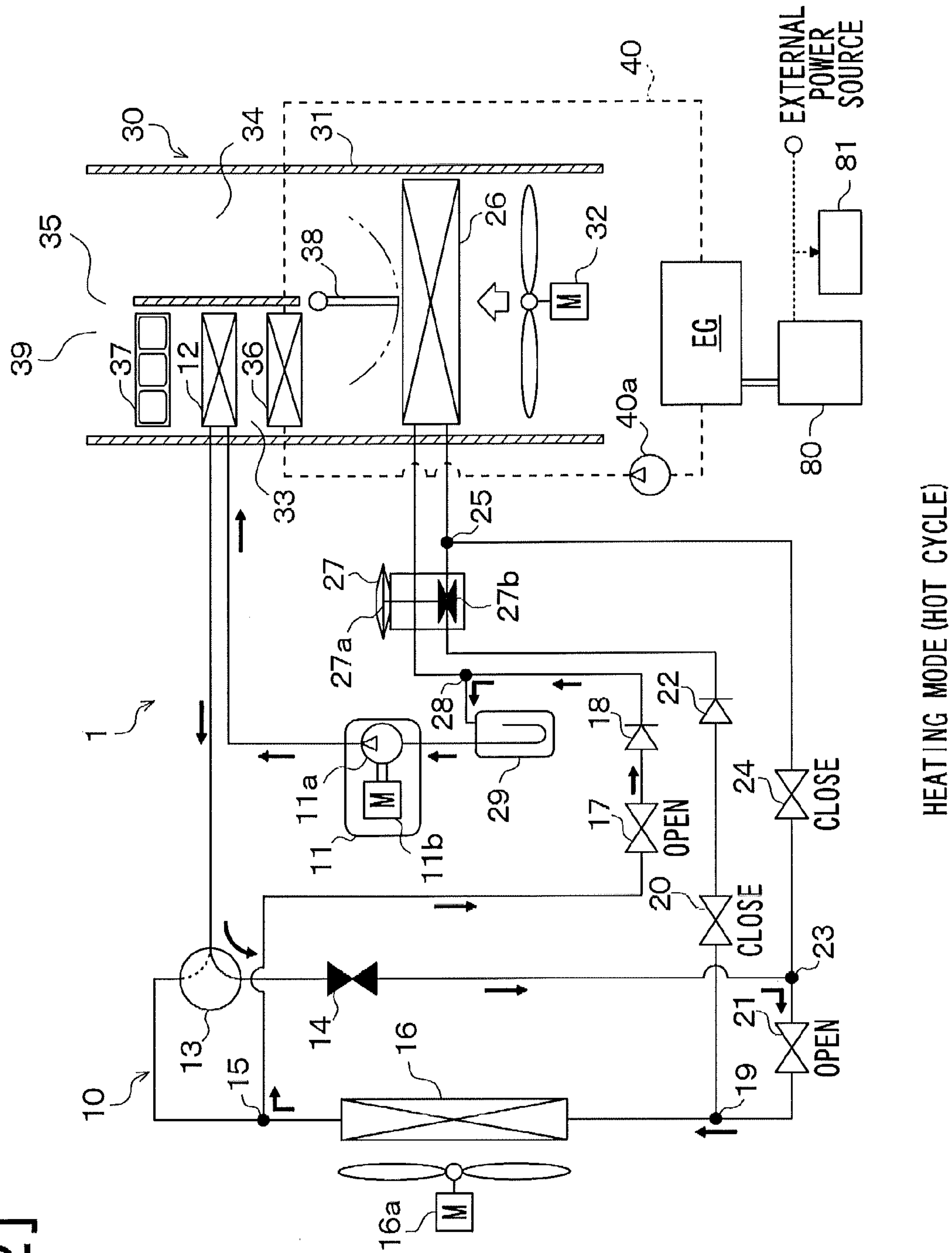
FIRST DEHUMIDIFICATION MODE (DRY_EVA CYCLE)

[FIG. 1]

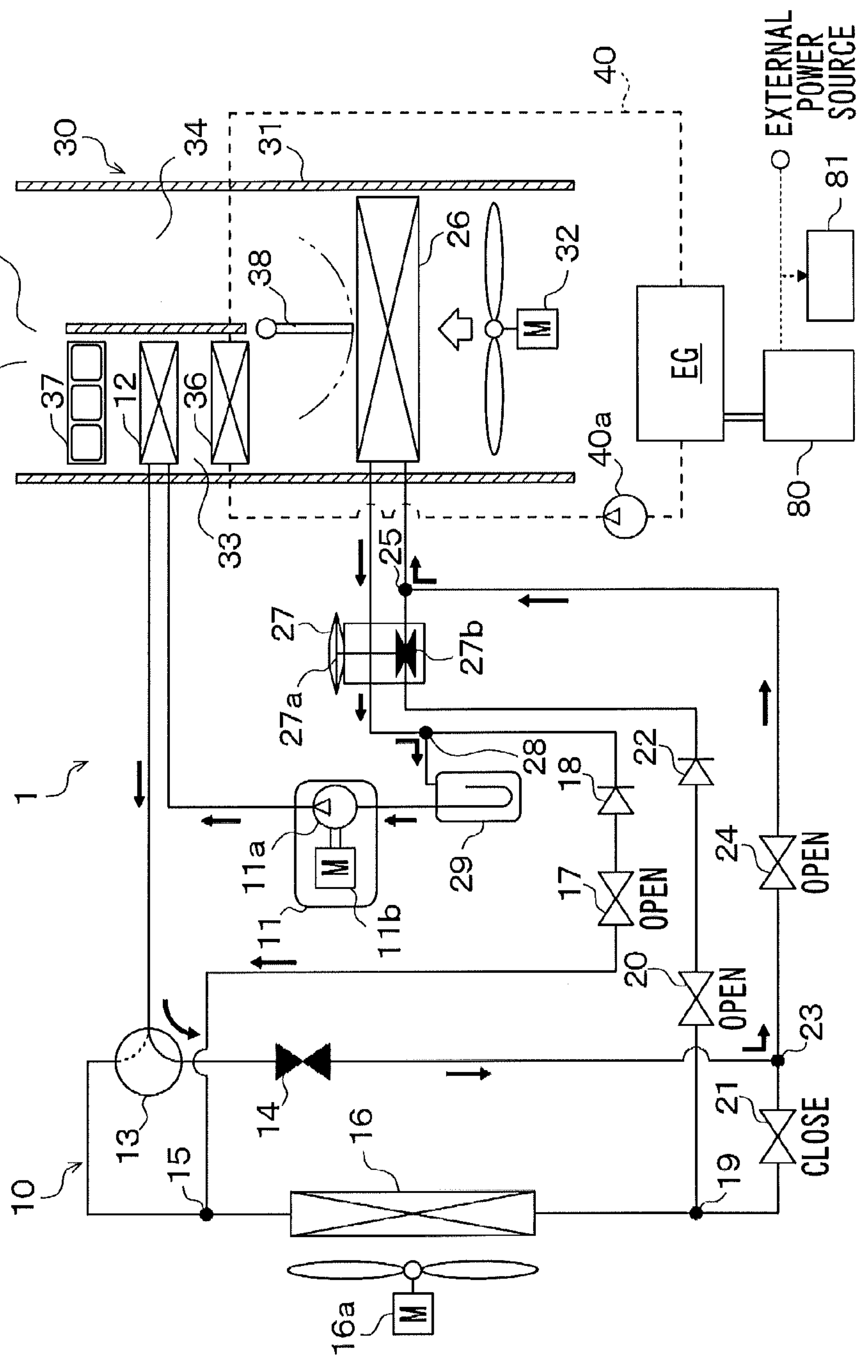


COOLING MODE (COOL CYCLE)

[FIG.2]

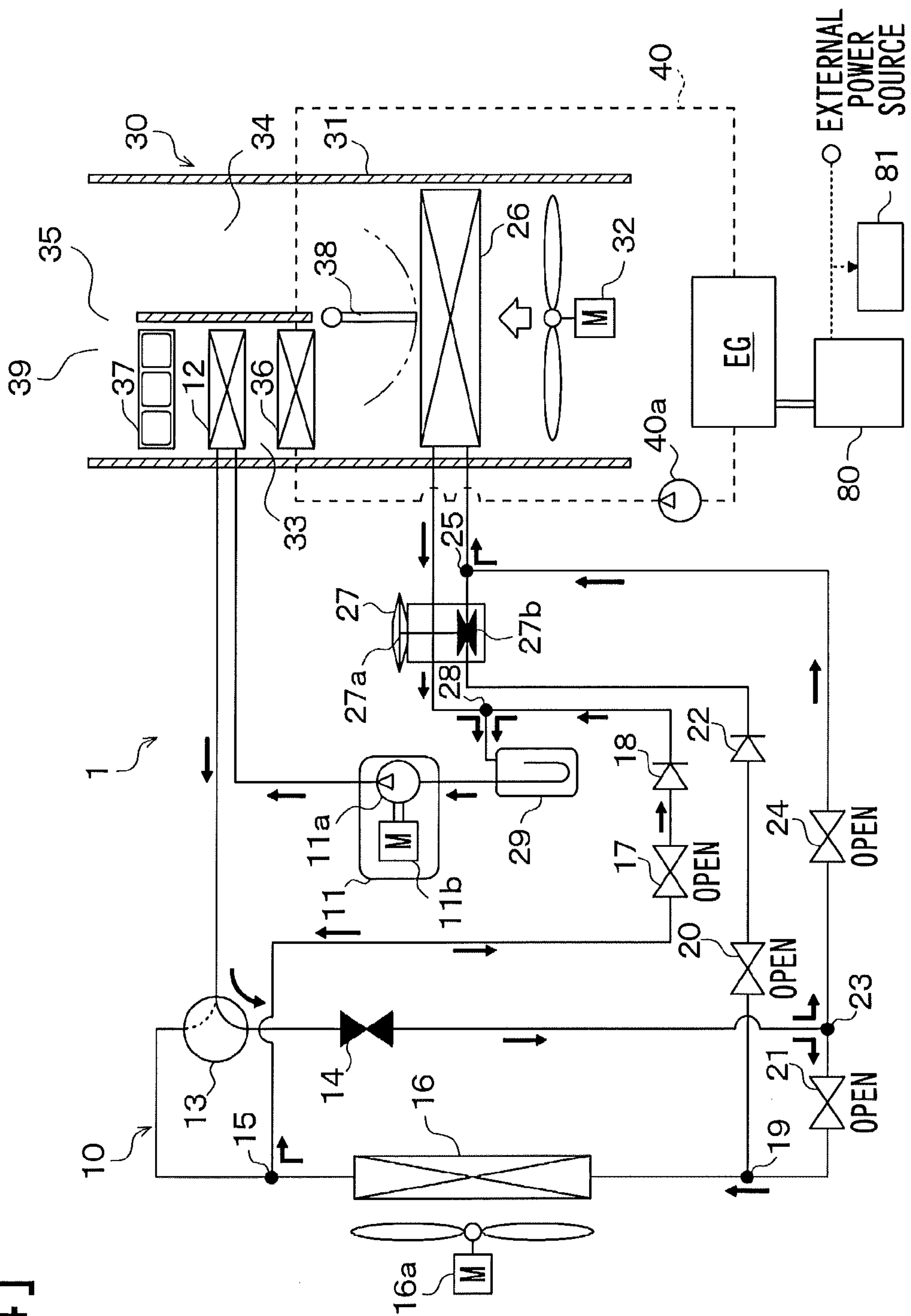

HEATING MODE (HOT CYCLE)
EXTERNAL POWER SOURCE
EG
M
OPEN
CLOSE
CLOSE
OPEN
CLOSE

[FIG.3]



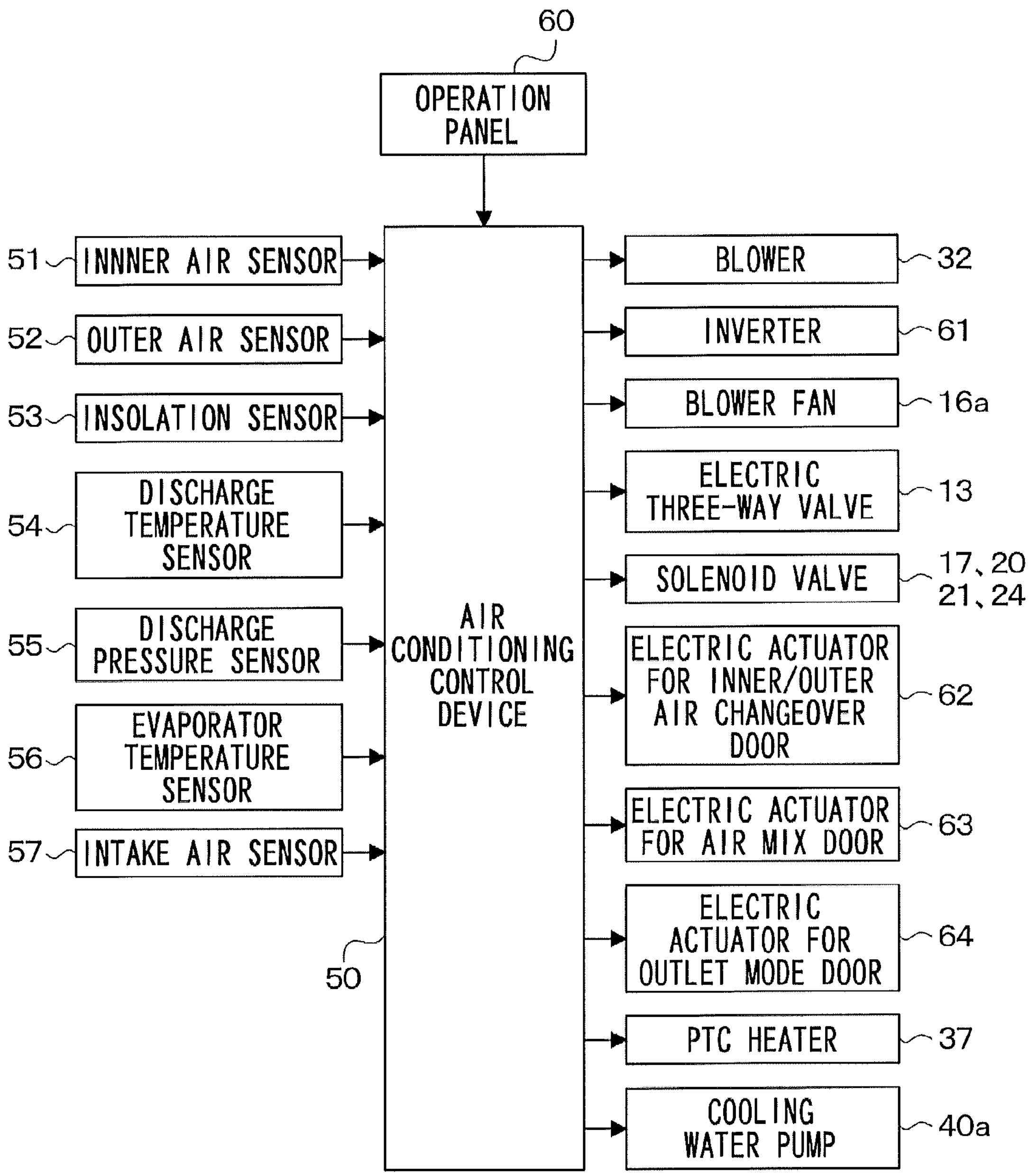
FIRST DEHUMIDIFICATION MODE (DRY_EVA CYCLE)

[FIG.4]

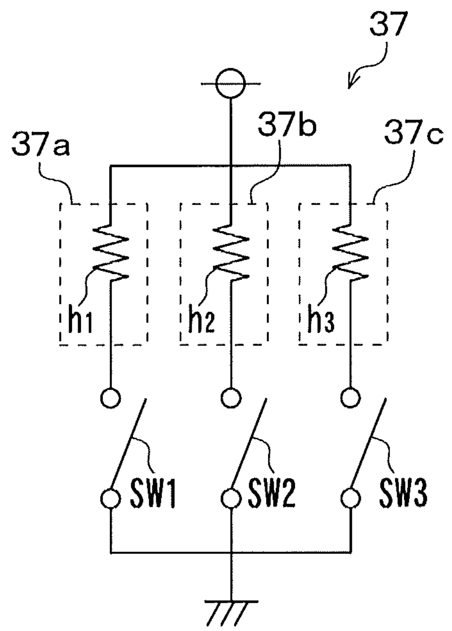


SECOND DEHUMIDIFICATION MODE (DRY_ALL CYCLE)

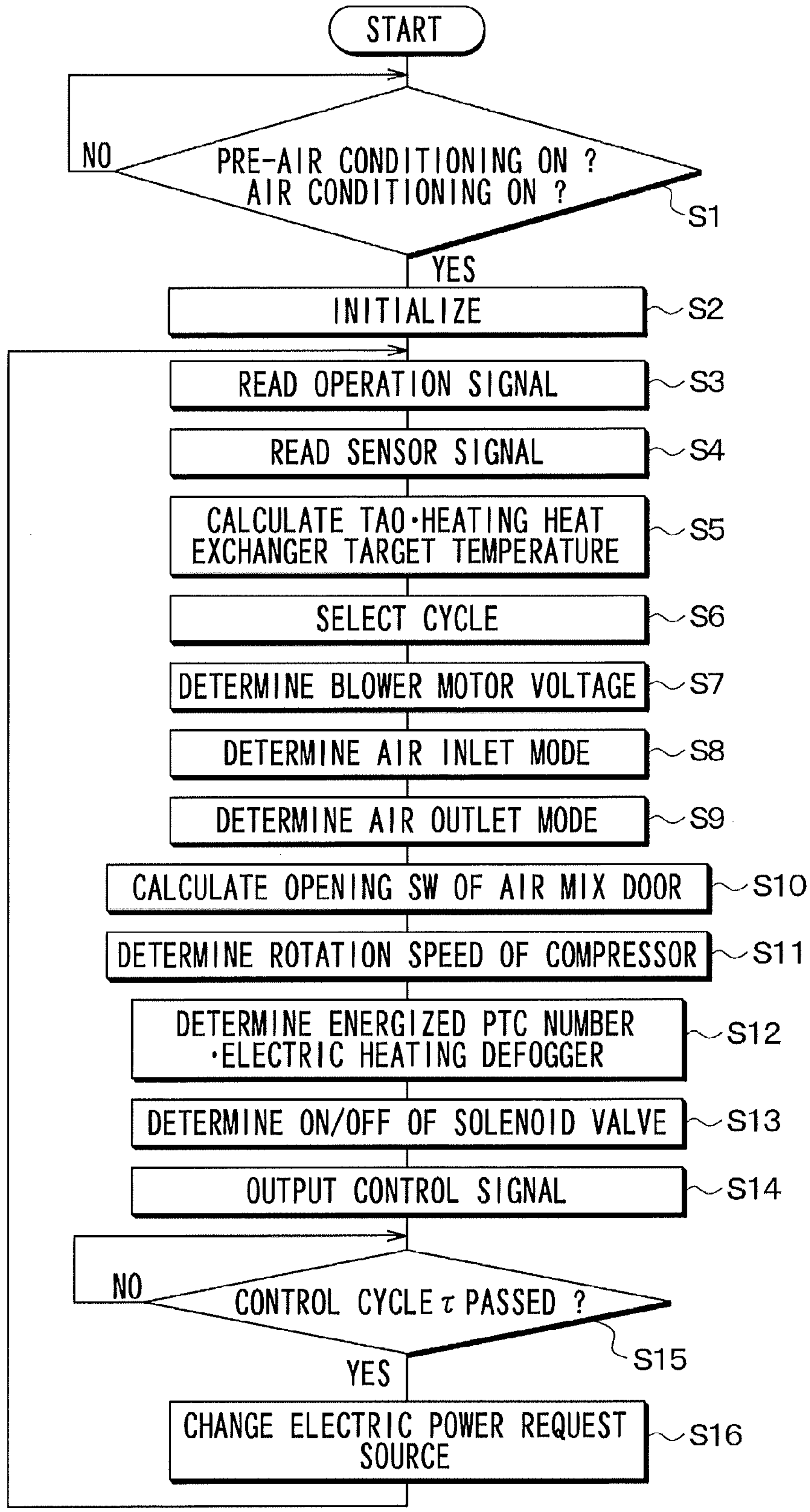
[FIG.5]


60
OPERATION PANEL
51 INNNER AIR SENSOR
52 OUTER AIR SENSOR
53 INSOLATION SENSOR
54 DISCHARGE TEMPERATURE SENSOR
55 DISCHARGE PRESSURE SENSOR
56 EVAPORATOR TEMPERATURE SENSOR
57 INTAKE AIR SENSOR
AIR CONDITIONING CONTROL DEVICE
50
BLOWER 32
INVERTER 61
BLOWER FAN 16a
ELECTRIC THREE-WAY VALVE 13
SOLENOID VALVE 17、20 21、24
ELECTRIC ACTUATOR FOR INNER/OUTER AIR CHANGEOVER DOOR 62
ELECTRIC ACTUATOR FOR AIR MIX DOOR 63
ELECTRIC ACTUATOR FOR OUTLET MODE DOOR 64
PTC HEATER 37
COOLING WATER PUMP 40a

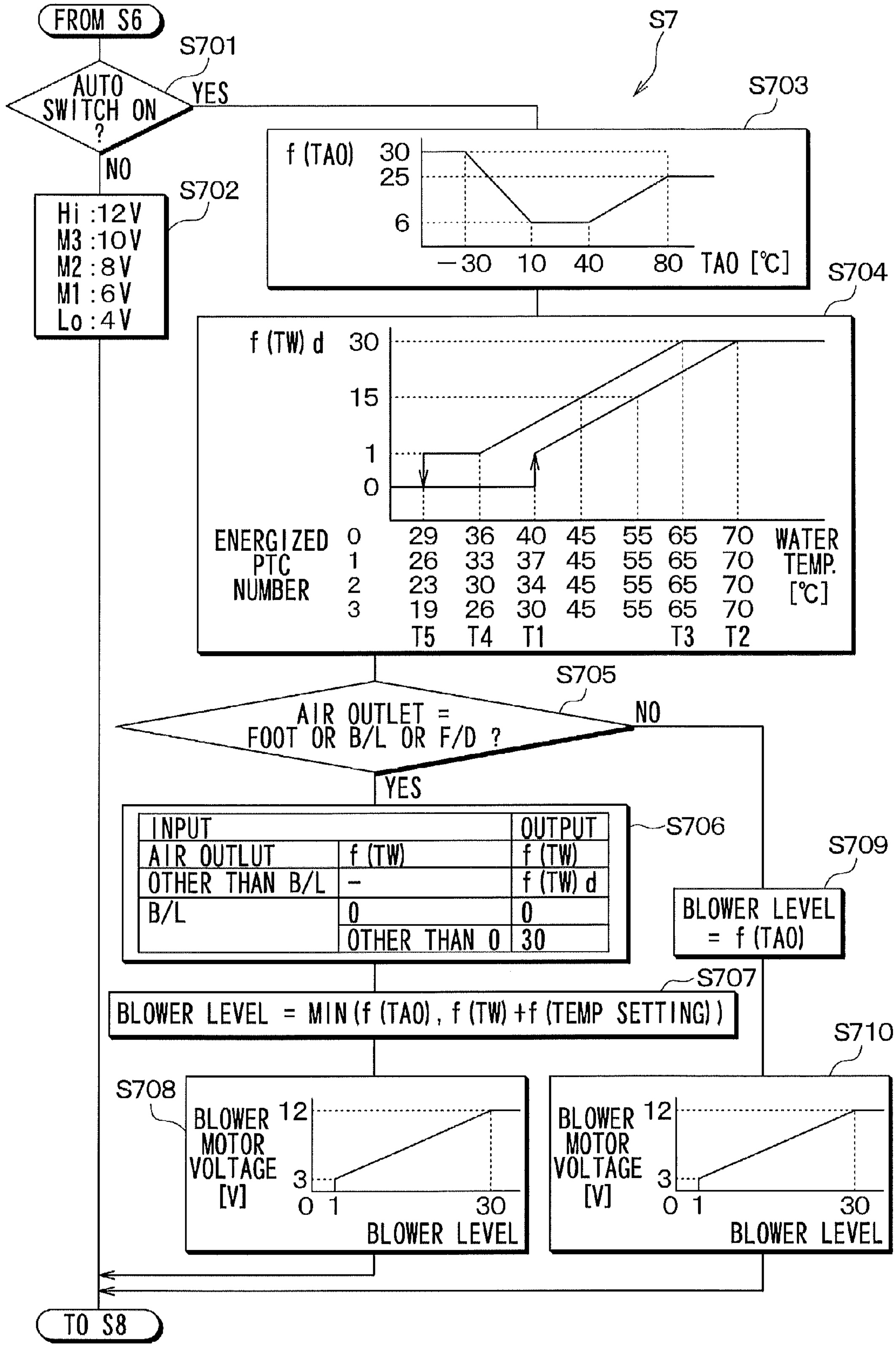
[FIG.6]



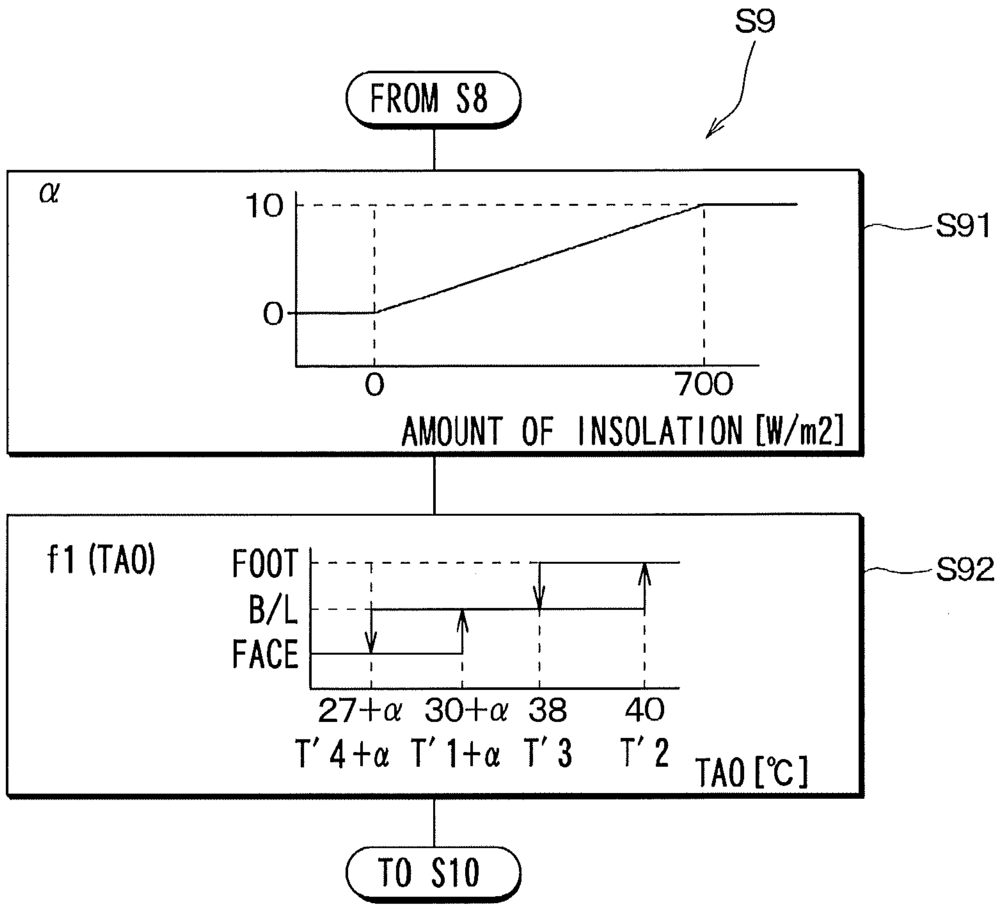
[FIG.7]


START
PRE-AIR CONDITIONING ON ?
AIR CONDITIONING ON ?
NO
YES
S1
INITIALIZE
S2
READ OPERATION SIGNAL
S3
READ SENSOR SIGNAL
S4
CALCULATE TAO·HEATING HEAT EXCHANGER TARGET TEMPERATURE
S5
SELECT CYCLE
S6
DETERMINE BLOWER MOTOR VOLTAGE
S7
DETERMINE AIR INLET MODE
S8
DETERMINE AIR OUTLET MODE
S9
CALCULATE OPENING SW OF AIR MIX DOOR
S10
DETERMINE ROTATION SPEED OF COMPRESSOR
S11
DETERMINE ENERGIZED PTC NUMBER ·ELECTRIC HEATING DEFOGGER
S12
DETERMINE ON/OFF OF SOLENOID VALVE
S13
OUTPUT CONTROL SIGNAL
S14
CONTROL CYCLE τ PASSED ?
NO
YES
S15
CHANGE ELECTRIC POWER REQUEST SOURCE
S16

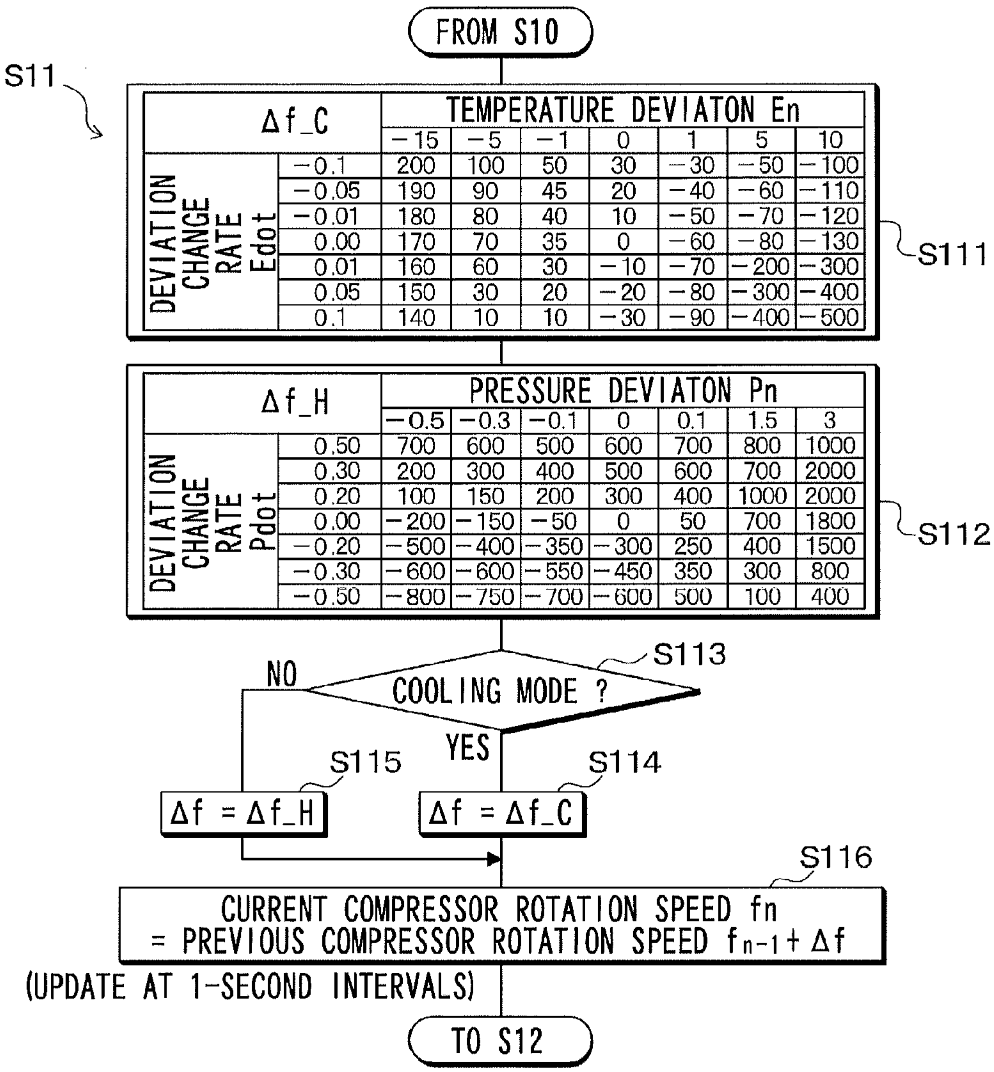
[FIG.8]


FROM S6
S701
AUTO SWITCH ON ?
YES
NO
S702
Hi :12V
M3 :10V
M2 :8V
M1 :6V
Lo :4V
S7
S703
f (TAO) 30 25 6
−30 10 40 80 TAO [℃]
S704
f (TW) d 30 15 1 0
ENERGIZED PTC NUMBER
0 29 36 40 45 55 65 70
1 26 33 37 45 55 65 70
2 23 30 34 45 55 65 70
3 19 26 30 45 55 65 70
T5 T4 T1 T3 T2
WATER TEMP. [℃]
S705
AIR OUTLET = FOOT OR B/L OR F/D ?
NO
YES
S706
INPUT
OUTPUT
AIR OUTLUT
f (TW)
f (TW)
OTHER THAN B/L
–
f (TW) d
B/L
0
0
OTHER THAN 0
30
S709
BLOWER LEVEL = f (TAO)
S707
BLOWER LEVEL = MIN (f (TAO), f (TW) +f (TEMP SETTING))
S708
BLOWER MOTOR VOLTAGE [V]
12 3 0 1 30
BLOWER LEVEL
S710
BLOWER MOTOR VOLTAGE [V]
12 3 0 1 30
BLOWER LEVEL
TO S8

[FIG.9]


S9
FROM S8
α
10
0
0
700
AMOUNT OF INSOLATION [W/m2]
S91
f1 (TAO)
FOOT
B/L
FACE
27+α
30+α
38
40
T'4+α
T'1+α
T'3
T'2
TAO [℃]
S92
TO S10

[FIG.10]



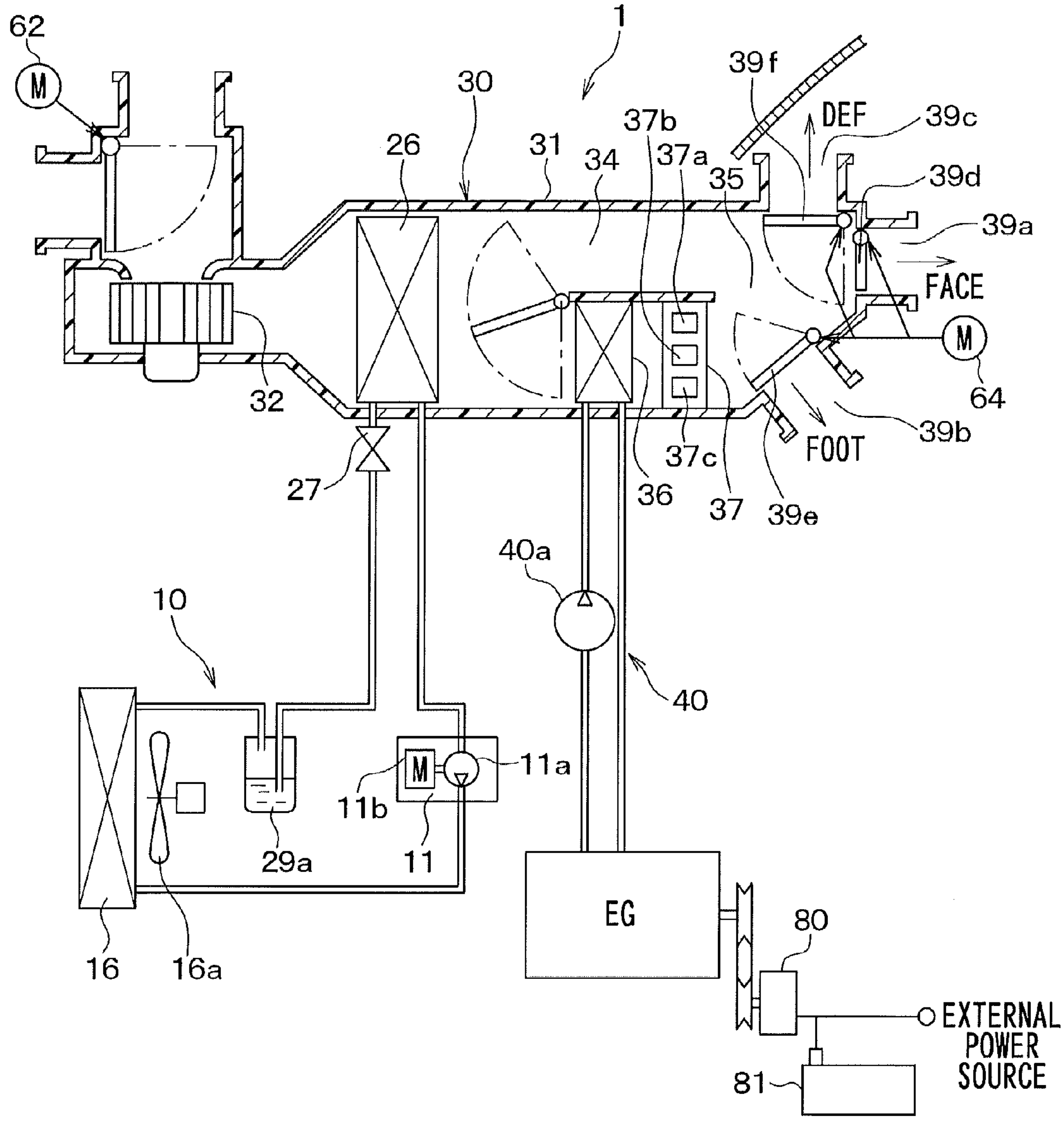
Δf_C		TEMPERATURE DEVIATON En						
		−15	−5	−1	0	1	5	10
DEVIATION CHANGE RATE Edot	−0.1	200	100	50	30	−30	−50	−100
	−0.05	190	90	45	20	−40	−60	−110
	−0.01	180	80	40	10	−50	−70	−120
	0.00	170	70	35	0	−60	−80	−130
	0.01	160	60	30	−10	−70	−200	−300
	0.05	150	30	20	−20	−80	−300	−400
	0.1	140	10	10	−30	−90	−400	−500

Δf_H		PRESSURE DEVIATON Pn						
		−0.5	−0.3	−0.1	0	0.1	1.5	3
DEVIATION CHANGE RATE Pdot	0.50	700	600	500	600	700	800	1000
	0.30	200	300	400	500	600	700	2000
	0.20	100	150	200	300	400	1000	2000
	0.00	−200	−150	−50	0	50	700	1800
	−0.20	−500	−400	−350	−300	250	400	1500
	−0.30	−600	−600	−550	−450	350	300	800
	−0.50	−800	−750	−700	−600	500	100	400

[FIG.11]

CYCLE_VALVE	ELE. 3-WAY VALVE	HI-VOLTAGE SOLENOID VALVE	LO-VOLTAGE SOLENOID VALVE	DEHUMID. SOLENOID VALVE	HEAT-EXCHANGE SHUT-OFF SOLENOID VALVE
COOL	OFF	OFF	OFF	OFF	OFF
HOT	ON	ON	ON	OFF	OFF
DRY_EVA	ON	OFF	ON	ON	ON
DRY_ALL	ON	OFF	ON	ON	OFF

[FIG.12]


62
M
1
30
31
26
34
37b
37a
35
39f
DEF
39c
39d
39a
FACE
M
64
32
27
36
37c
37
39e
FOOT
39b
40a
10
40
M
11a
11b
29a
11
16
16a
EG
80
EXTERNAL
POWER
SOURCE
81

AIR CONDITIONER FOR VEHICLE

TECHNICAL FIELD

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

BACKGROUND ART

[0002] In a conventional air conditioner for a vehicle, control is exercised to stop a blower when an engine cooling water temperature is not higher than a predetermined temperature, start the blower when the engine cooling water temperature becomes higher than the predetermined temperature, and increase the amount of air blown from the blower when the engine cooling water temperature rises (refer, for instance, to PTL 1). This inhibits an occupant of the vehicle from feeling unwarmed as the blower blows insufficiently heated air to the feet of the occupant if the engine cooling water temperature is low when, for instance, a heater is started.

CITATION LIST

Patent Literature

[PTL 1]

[0003] Japanese Patent Application Publication No. 2769073

SUMMARY OF INVENTION

Technical Problem

[0004] However, when the invention described in PTL 1 is employed, the temperature of the engine cooling water (a heat medium for heating the blown air) needs to be raised in order to increase the rate of air flow. Therefore, if the temperature of the engine cooling water is low, the occupant feels hot at the upper body (especially, the face) and looses comfortable feeling under strong solar radiation because the rate of air flow from a face air outlet is very small in a bi-level mode.

[0005] In light of the foregoing, it is an object of the present invention to provide an air conditioner for a vehicle that is capable of improving comfort of an occupant when solar radiation is strong.

Solution to Problem

[0006] In order to achieve the object, a first aspect of the present invention includes a blower that generates blown air; a heating heat exchanger that heats the blown air by heat exchange between the blown air and a heat medium; a control device that determines the availability factor of the blower; and an air outlet mode switching device that switches between a plurality of air outlet modes by switching proportions of air flow blown out from a plurality of outlets which includes a face air outlet that blows out the blown air to an upper body of an occupant and a foot air outlet that blows out the blown air to a lower body of an occupant, wherein the control device: limits the availability factor of the blower based on a temperature of the heat medium; and relaxes limitation on the availability factor of the blower when the air outlet mode is a bi-level mode in which the blown air is blown out from both of the face air outlet and the foot air outlet.

[0007] With this aspect, limitation on the availability factor of the blower is relaxed. Therefore, it is possible to increase the amount of the air flow blown out from the face air outlet even if the temperature of the heat medium is not sufficiently high. As a result, it is possible to improve comfort of the occupant when solar radiation is strong.

[0008] In a second aspect of the present invention according to the first aspect, the control device: determines the availability factor of the blower based on an air-conditioning load; determines an upper limit of the availability factor based on the temperature of the heat medium; limits the availability factor of the blower so that the availability factor of the blower is equal to or smaller than the upper limit when the air outlet mode is a mode in which the blown air is blown out at least from the foot air outlet; and determines the upper limit to be equal to or larger than the availability factor of the blower that is determined based on the air-conditioning load when the air outlet mode is the bi-level mode.

[0009] This makes it possible, while in the bi-level mode, to cancel the effect of the limitation on the availability factor of the blower that is caused by the temperature of the heat medium. Therefore, it is possible to surely increase the amount of the air flow blown out from the face air outlet.

[0010] In a third aspect of the present invention according to the first or second aspect, the control device does not relax the limitation on the availability factor of the blower when the engine cooling water temperature is smaller than a certain temperature even if the air outlet mode is the bi-level mode.

[0011] With this operation, it is possible to prevent the amount of the air flow blown out from the foot air outlet from increasing when the engine cooling water temperature is smaller than a certain temperature. Therefore, it is possible to ease the occupant's feeling that his/her feet are receiving cold wind when the blown air temperature is very low.

[0012] A fourth aspect of the present invention according to the third aspect, comprises an auxiliary heating means (**37**) that heats the blown air, wherein the control means (**50**) sets the certain temperature so that the certain temperature is smaller when the auxiliary heating means is operating than when the auxiliary heating means is not operating.

[0013] With this operation, it is possible to relax the limitation on the availability factor of the blower (**32**) when the auxiliary heating means (**37**) is operating even if the temperature of the heat medium is low. In addition, when the auxiliary heating means (**37**) is operating, it is possible to increase the blown air temperature even if the temperature of the heat medium is low. Therefore, the occupant's feeling that his/her feet are receiving cold wind is eased. As a result, it is possible to improve, when solar radiation is strong, comfort of the occupant without harming the occupant's feeling that he/she is in a warmed room.

[0014] In a fifth aspect of the present invention according to any one of the first to fourth aspects, the control means (**50**): limits the availability factor of the blower (**32**) based on the temperature of the heat medium when the air outlet mode is the bi-level mode; when the air outlet mode is a face mode in which the blown air is blown out from the face air outlet (**39***a*), reduces limitation on the availability factor of the blower (**32**) compared to when in the bi-level mode; and controls the air outlet mode so that, in accordance with increase of an amount of insolation, it becomes more unlikely that the air outlet mode is determined to be the bi-level mode, and it becomes more likely that the air outlet mode is determined to be the face mode.

[0015] In a sixth aspect of the present invention includes a blower (**32**) that generates blown air; a heating heat exchanger (**36**) that heats the blown air by heat exchange between the blown air and a heat medium; an air outlet mode switching means (**39***d*, **39***e*, **39***f*) that switches between a plurality of air outlet modes by switching proportions of air flow blown out from a plurality of outlets (**39***a*, **39***b*, **39***c*) which includes a face air outlet (**39***a*) that blows out the blown air to an upper body of an occupant and a foot air outlet (**39***b*) that blows out the blown air to a lower body of an occupant, and a control means (**50**) that determines the availability factor of the blower (**32**) and the air outlet mode, wherein the control means (**50**): limits the availability factor of the blower (**32**) based on a temperature of the heat medium when the air outlet mode is a bi-level mode in which the blown air is blown out from both of the face air outlet (**39***a*) and the foot air outlet (**39***b*); when the air outlet mode is a face mode in which the blown air is blown out from the face air outlet (**39***a*), reduces limitation on the availability factor of the blower (**32**) compared to when in the bi-level mode; and controls the air outlet mode so that, in accordance with increase of an amount of insolation, it becomes more unlikely that the air outlet mode is determined to be the bi-level mode, and it becomes more likely that the air outlet mode is determined to be the face mode.

[0016] With this operation, the larger the amount of the insolation becomes, the more unlikely it becomes that the air outlet mode is determined to be the bi-level mode, and the more likely it becomes that the air outlet mode is determined to be the face mode. Therefore, it is possible to improve comfort of the occupant by increasing the amount of the air flow blown out from the face air outlet (**39***a*) when solar radiation is strong.

[0017] In addition, since the proportion of the amount of the air flow blown out from the foot air outlet (**39***b*) is smaller in the face mode than in the bi-level mode, it is possible to ease the occupant's feeling that his/her feet is receiving cold wind if it becomes more likely that the air outlet mode is determined to be the face mode.

[0018] In a seventh aspect of the present invention according to the sixth aspect, the control means (**50**): determines the availability factor of the blower (**32**) based on an air-conditioning load; and in accordance with increase of the amount of the insolation, narrows down a range of the air-conditioning load in which the air outlet mode is determined to be the bi-level mode is narrowed, and widens a range of the air-conditioning load in which the air outlet mode is determined to be the face mode.

[0019] With this operation, the larger the amount of the insolation becomes, the more unlikely it becomes that the air outlet mode is determined to be the bi-level mode, and the more likely it becomes that the air outlet mode is determined to be the face mode.

[0020] Parenthesized reference signs of the means described here and under CLAIMS correlate to those of specific means described later under "Description of Embodiments."

BRIEF DESCRIPTION OF DRAWINGS

[0021] FIG. **1** is a diagram illustrating the overall configuration of a refrigerant circuit for a cooling mode of an air conditioner for a vehicle according to a first embodiment of the present invention.

[0022] FIG. **2** is a diagram illustrating the overall configuration of a refrigerant circuit for a heating mode of the air conditioner for a vehicle according to the first embodiment.

[0023] FIG. **3** is a diagram illustrating the overall configuration of a refrigerant circuit for a first dehumidification mode of the air conditioner for a vehicle according to the first embodiment.

[0024] FIG. **4** is a diagram illustrating the overall configuration of a refrigerant circuit for a second dehumidification mode of the air conditioner for a vehicle according to the first embodiment.

[0025] FIG. **5** is a block diagram illustrating an electrical control section of the air conditioner for a vehicle according to the first embodiment.

[0026] FIG. **6** is a circuit diagram illustrating a PTC heater according to the first embodiment.

[0027] FIG. **7** is a flowchart illustrating a control process performed by the air conditioner for a vehicle according to the first embodiment.

[0028] FIG. **8** is a flowchart illustrating an essential portion of the control process performed by the air conditioner for a vehicle according to the first embodiment.

[0029] FIG. **9** is a flowchart illustrating another essential portion of the control process performed by the air conditioner for a vehicle according to the first embodiment.

[0030] FIG. **10** is a flowchart illustrating another essential portion of the control process performed by the air conditioner for a vehicle according to the first embodiment.

[0031] FIG. **11** is a table illustrating the operating states of solenoid valves in various operation modes according to the first embodiment.

[0032] FIG. **12** is a diagram illustrating the overall configuration of the air conditioner for a vehicle according to a second embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0033] Embodiments of the present invention will now be described with reference to the accompanying drawings. In the drawings depicting the embodiments, portions identical or equivalent to each other are designated by the same reference signs.

First Embodiment

[0034] A first embodiment of the present invention will now be described with reference to FIGS. **1** to **11**. FIGS. **1** to **4** are diagrams illustrating the overall configuration of an air conditioner for a vehicle according to the first embodiment. FIG. **5** is a block diagram illustrating an electrical control section of the air conditioner for a vehicle **1**. In the present embodiment, the air conditioner for a vehicle is applied to a hybrid vehicle that acquires a driving force for running the vehicle from an internal combustion engine EG and from a driving electric motor.

[0035] The hybrid vehicle according to the present embodiment is a so-called plug-in hybrid vehicle capable of charging its battery **81** with electricity supplied from an external power source (commercial power source) while the vehicle is stopped. If the battery **81** is charged by the external power source while the vehicle is stopped before running so that the amount of electrical power remaining in the battery **81** is not smaller than a predetermined driving reference amount as at the beginning of running, the plug-in hybrid vehicle runs by mainly using the driving force generated by the driving electric motor (this driving mode is referred to as the EV driving mode).

[0036] If, on the other hand, the amount of electrical power remaining in the battery **81** is smaller than the predetermined driving reference amount while the vehicle is running, the plug-in hybrid vehicle runs by mainly using the driving force generated by the engine EG (this driving mode is referred to as the HV driving mode). The plug-in hybrid vehicle switches between the EV driving mode and the HV driving mode as described above to achieve improved fuel economy, or more specifically, cause the engine EG to consume a smaller amount of fuel than a normal vehicle that acquires the driving force for running the vehicle from the engine EG alone.

[0037] The EV driving mode is a driving mode in which the vehicle runs by mainly using the driving force output from the driving electric motor. However, if a vehicle driving load is high in the EV driving mode, the engine EG is operated to assist the driving electric motor. Meanwhile, the HV driving mode is a driving mode in which the vehicle runs by mainly using the driving force output from the engine EG. Similarly, however, if the vehicle driving load is high in the HV driving mode, the driving electric motor is operated to assist the engine EG. The above operations of the engine EG and of the driving electric motor are controlled by an engine control device (not shown).

[0038] Further, the driving force output from the engine EG is used not only for running the vehicle but also for operating a generator **80**. Electrical power generated by the generator **80** and electrical power supplied from the external power source can be stored in the battery **81**. The electrical power stored in the battery **81** can be supplied not only to the driving electric motor but also to various vehicle-mounted devices such as components of the air conditioner for a vehicle **1**.

[0039] The configuration of the air conditioner for a vehicle **1** according to the present embodiment will now be described in detail. The air conditioner for a vehicle **1** is capable of not only providing normal air conditioning in a passenger compartment of the vehicle during the vehicle run, but also providing pre-air conditioning in order to provide air conditioning in the passenger compartment while the battery **81** is being charged by the external power source before an occupant enters the vehicle.

[0040] The air conditioner for a vehicle **1** has a vapor compression type refrigeration cycle **10** that selectively uses, during normal air conditioning and pre-air conditioning, a refrigerant circuit for a cooling mode (COOL cycle) for cooling the passenger compartment, a refrigerant circuit for a heating mode (HOT cycle) for heating the passenger compartment, a refrigerant circuit for a first dehumidification mode (DRY_EVA cycle) for dehumidifying the passenger compartment, and a refrigerant circuit for a second dehumidification mode (DRY_ALL cycle) for dehumidifying the passenger compartment.

[0041] FIGS. **1** to **4** use solid arrows to indicate the flow of a refrigerant in the cooling mode, the heating mode, the first dehumidification mode, or the second dehumidification mode. The first dehumidification mode is a dehumidification mode in which a dehumidification capacity takes precedence over a heating capacity, whereas the second dehumidification mode is a dehumidification mode in which the heating capacity takes precedence over the dehumidification capacity. Hence, the first dehumidification mode may be referred to as a low-temperature dehumidification mode or a simple dehumidification mode, whereas the second dehumidification mode may be referred to as a high-temperature dehumidification mode or a dehumidification-heating mode.

[0042] The refrigeration cycle **10** includes, for example, a compressor **11**, an indoor condenser **12**, an indoor evaporator **26**, a thermostatic expansion valve **27**, a fixed throttle **14**, and a plurality of solenoid valves **13**, **17**, **20**, **21**, **24** (five solenoid valves in the present embodiment). The indoor condenser **12** and the indoor evaporator **26** act as an indoor heat exchanger. The thermostatic expansion valve **27** and the fixed throttle **14** act as a pressure reduction means for decompressing and expanding the refrigerant. The solenoid valves **13**, **17**, **20**, **21**, **24** act as a refrigerant circuit selection means. The refrigeration cycle **10** functions as a temperature regulation means for regulating the temperature of air blown into the passenger compartment.

[0043] Further, the refrigeration cycle **10** uses a normal Freon refrigerant and constitutes a subcritical refrigeration cycle in which the high pressure side of the refrigerant pressure does not exceed its critical pressure. Moreover, a refrigerant oil for lubricating the compressor **11** is mixed with the refrigerant. Part of the refrigerant oil circulates through the cycle together with the refrigerant.

[0044] The compressor **11** is disposed in an engine room. In the refrigeration cycle **10**, the compressor **11** sucks, compresses, and discharges the refrigerant. The compressor **11** is configured as an electric compressor in which an electric motor **11*b*** drives a fixed-capacity compression mechanism **11*a*** having a fixed discharge capacity. Specifically, a scroll-type compression mechanism, a vane-type compression mechanism, and various other compression mechanisms may be used as the fixed-capacity compression mechanism **11*a***.

[0045] The electric motor **11*b*** is an AC motor whose operation (rotation speed) is controlled by an AC voltage output from an inverter **61**. The inverter **61** also outputs an AC voltage having a frequency corresponding to a control signal output from a later-described air-conditioning control device **50**. This rotation speed control changes the refrigerant discharge capability of the compressor **11**. Therefore, the electric motor **11*b*** constitutes a means for changing the discharge capability of the compressor **11**.

[0046] The discharge side of the compressor **11** is connected to the refrigerant inlet side of the indoor condenser **12**. The indoor condenser **12** is a heating heat exchanger that is disposed in a casing **31**, which forms an air path in an indoor air-conditioning unit **30** of the air conditioner for a vehicle for the air blown into the passenger compartment, and heats the blown air by heat exchange between the refrigerant distributed in the indoor condenser **12** and the blown air after passing through the later-described indoor evaporator **26**. The indoor air-conditioning unit **30** will be described in detail later.

[0047] The refrigerant outlet side of the indoor condenser **12** is connected to an electric three-way valve **13**. The electric three-way valve **13** is a refrigerant circuit selection means whose operation is controlled by a control voltage output from the air-conditioning control device **50**.

[0048] More specifically, in an energized state in which electrical power is supplied, the electric three-way valve **13** switches to a refrigerant circuit that connects the refrigerant outlet side of the indoor condenser **12** to the refrigerant inlet side of the fixed throttle **14**. In a de-energized state in which the supply of electrical power is shut off, the electric three-way valve **13** switches to a refrigerant circuit that connects the refrigerant outlet side of the indoor condenser **12** to one refrigerant inflow outlet of a first three-way joint **15**.

[0049] The fixed throttle **14** is a decompression means for heating and dehumidification that decompresses and expands the refrigerant that flows out of the electric three-way valve **13** in the heating mode, the first dehumidification mode, or the second dehumidification mode. A capillary tube, an orifice, or the like may be used as the fixed throttle **14**. Obviously, an electric variable throttle mechanism whose throttle path area is adjusted by a control signal output from the air-conditioning control device **50** may be employed as the decompression means for heating and dehumidification. The refrigerant outlet side of the fixed throttle **14** is connected to the refrigerant inflow outlet of a later-described third three-way joint **23**.

[0050] The first three-way joint **15** has three refrigerant inflow outlets and functions as a joint for branching a refrigerant flow path. This three-way joint may be formed by joining refrigerant pipes or by attaching a plurality of refrigerant paths to a metal block or a plastic block. Another refrigerant inflow outlet of the first three-way joint **15** is connected to one refrigerant inflow outlet of an outdoor heat exchanger **16**. Still another refrigerant inflow outlet of the first three-way joint **15** is connected to the refrigerant inlet side of a low-voltage solenoid valve **17**.

[0051] The low-voltage solenoid valve **17** includes a valve body, which opens and closes a refrigerant flow path, and a solenoid (coil), which drives the valve body. The low-voltage solenoid valve **17** acts as a refrigerant circuit selection means whose operation is controlled by a control voltage output from the air-conditioning control device **50**. More specifically, the low-voltage solenoid valve **17** is configured as a so-called normally-closed valve that opens in an energized state and closes in a de-energized state.

[0052] The refrigerant outlet side of the low-voltage solenoid valve **17** is connected to one refrigerant inflow outlet of a later-described fifth three-way joint **28** through a first check valve **18**. The first check valve **18** permits the refrigerant to flow in a single direction from the low-voltage solenoid valve **17** side to the fifth three-way joint **28** side.

[0053] The outdoor heat exchanger **16** is disposed in the engine room to provide heat exchange between the internally distributed refrigerant and outer air (air taken in from the outside of the passenger compartment and supplied from a blower fan **16***a*). The blower fan **16***a* is an electric blower whose rotation speed (the amount of blown air) is controlled by a control voltage output from the air-conditioning control device **50**.

[0054] It should also be noted that the blower fan **16***a* according to the present embodiment supplies the outer air not only to the outdoor heat exchanger **16** but also to a radiator (not shown) that dissipates the heat of cooling water for the engine EG. Specifically, the air taken in from the outside of the passenger compartment and supplied from the blower fan **16***a* flows to the outdoor heat exchanger **16** and then to the radiator. The radiator is connected to a cooling water piping that forms a cooling water circuit **40** indicated by broken lines in FIGS. **1** to **4**. The cooling water circuit **40** will be described later.

[0055] A cooling water pump is disposed in the cooling water circuit, which is indicated by the broken lines in FIGS. **1** to **4**, to circulate the cooling water. The cooling water pump **40***a* is an electric water pump whose rotation speed (cooling water circulation volume) is controlled by a control voltage output from the air-conditioning control device **50**.

[0056] The other refrigerant inflow outlet of the outdoor heat exchanger **16** is connected to one refrigerant inflow outlet of a second three-way joint **19**. The basic configuration of the second three-way joint **19** is the same as that of the first three-way joint **15**. Another refrigerant inflow outlet of the second three-way joint **19** is connected to the refrigerant inlet side of a high-voltage solenoid valve **20**. Still another refrigerant inflow outlet of the second three-way joint **19** is connected to one refrigerant inflow outlet of a heat exchanger shut-off solenoid valve **21**.

[0057] The high-voltage solenoid valve **20** and the heat exchanger shut-off solenoid valve **21** are refrigerant circuit selection means whose operation is controlled by a control voltage output from the air-conditioning control device **50**. The high-voltage solenoid valve **20** and the heat exchanger shut-off solenoid valve **21** have the same basic configuration as the low-voltage solenoid valve **17**. However, the high-voltage solenoid valve **20** and the heat exchanger shut-off solenoid valve **21** are configured as a so-called normally-open valve that closes in an energized state and opens in a de-energized state.

[0058] The refrigerant outlet side of the high-voltage solenoid valve **20** is connected to the inlet side of a throttle mechanism portion of the later-described thermostatic expansion valve **27** through a second check valve **22**. The second check valve **22** permits the refrigerant to flow in a single direction from the high-voltage solenoid valve **20** side to the thermostatic expansion valve **27** side.

[0059] The other refrigerant inflow outlet of the heat exchanger shut-off solenoid valve **21** is connected to one refrigerant inflow outlet of the third three-way joint **23**. The third three-way joint **23** has the same basic configuration as the first three-way joint **15**. Another refrigerant inflow outlet of the third three-way joint **23** is connected to the refrigerant outlet side of the fixed throttle **14** as mentioned earlier. Still another refrigerant inflow outlet of the third three-way joint **23** is connected to the refrigerant inlet side of a dehumidification solenoid valve **24**.

[0060] The dehumidification solenoid valve **24** is a refrigerant circuit selection means whose operation is controlled by a control voltage output from the air-conditioning control device **50**. The basic configuration of the dehumidification solenoid valve **24** is the same as that of the low-voltage solenoid valve **17**. The dehumidification solenoid valve **24** is also configured as a normally-closed valve. The refrigerant circuit selection means according to the present embodiment is formed by a plurality of (five) solenoid valves, namely, the electric three-way valve **13**, low-voltage solenoid valve **17**, high-voltage solenoid valve **20**, heat exchanger shut-off solenoid valve **21**, and dehumidification solenoid valve **24**, which are placed in a predefined open state or closed state when the supply of electrical power is shut off.

[0061] The refrigerant outlet side of the dehumidification solenoid valve **24** is connected to one refrigerant inflow outlet of a fourth three-way joint **25**. The fourth three-way joint **25** has the same basic configuration as the first three-way joint **15**. Another refrigerant inflow outlet of the fourth three-way joint **25** is connected to the outlet side of the throttle mechanism portion of the thermostatic expansion valve **27**. Still another refrigerant inflow outlet of the fourth three-way joint **25** is connected to the refrigerant inlet side of the indoor evaporator **26**.

[0062] The indoor evaporator **26** is a cooling heat exchanger that is mounted in the casing **31** of the indoor air-conditioning unit **30** and disposed upstream of the indoor condenser **12** with respect to the flow of blown air to cool the blown air by heat exchange between the refrigerant distributed in the indoor evaporator **26** and the blown air.

[0063] The refrigerant outlet of the indoor evaporator **26** is connected to the inlet side of a thermosensitive-portion of the thermostatic expansion valve **27**. The thermostatic expansion valve **27** is a pressure reduction means for cooling that decompresses and expands the refrigerant flowing into the inside from the inlet of the throttle mechanism portion and causes the refrigerant to flow out of the outlet of the throttle mechanism portion.

[0064] More specifically, the thermostatic expansion valve **27** according to the present embodiment is an internal pressure balancing expansion valve placed in a housing that contains the thermosensitive portion **27***a* and the variable throttle mechanism portion **27***b*. The thermosensitive portion **27***a* detects the degree of overheat of the refrigerant at the outlet side of the indoor evaporator **26** in accordance with the temperature and pressure of the refrigerant at the outlet side of the indoor evaporator **26**. The variable throttle mechanism portion **27***b* adjusts the throttle path area (refrigerant flow rate) so that the degree of overheat of the refrigerant at the outlet side of the indoor evaporator **26** is within a predetermined range in accordance with the displacement of the thermosensitive portion **27***a*.

[0065] The outlet side of the thermosensitive-portion of the thermostatic expansion valve **27** is connected to one refrigerant inflow outlet of the fifth three-way joint **28**. The basic configuration of the fifth three-way joint **28** is the same as that of the first three-way joint **15**. Another refrigerant inflow outlet of the fifth three-way joint **28** is connected to the refrigerant outlet side of the first check valve **18** as mentioned earlier. Still another refrigerant inflow outlet of the fifth three-way joint **28** is connected to the refrigerant inlet side of an accumulator **29**.

[0066] The accumulator **29** is a low-pressure side gas-liquid separator that receives the refrigerant from the fifth three-way joint **28**, separates the received refrigerant into a gas and a liquid, and stores an excess refrigerant. The gas-phase refrigerant outlet of the accumulator **29** is connected to the refrigerant inlet of the compressor **11**.

[0067] The indoor air-conditioning unit **30** will now be described. The indoor air-conditioning unit **30** is disposed inside an instrument panel at the forefront of the passenger compartment. The casing **31**, which is the outer shell of the indoor air-conditioning unit **30**, houses, for example, a blower **32**, the indoor evaporator **26**, the indoor condenser **12**, a heater core **36**, and a PTC heater **37**.

[0068] The casing **31** forms a path for the air blown into the passenger compartment, is elastic to a certain degree, and is molded with resin that excels in strength (e.g., polypropylene). An inner/outer air changeover box (not shown) is disposed at the most upstream end within the casing **31** with respect to the flow of blown air to selectively introduce inner air (the air inside the passenger compartment) and outer air (the air outside the passenger compartment).

[0069] More specifically, the inner/outer air changeover box is provided with an inner air introduction port for introducing the inner air into the casing **31** and an outer air introduction port for introducing the outer air into the casing **31**. Further, an inner/outer air changeover door is disposed in the inner/outer air changeover box to continuously adjust the opening areas of the inner and outer air introduction ports for the purpose of changing the ratio between the amount of inner air introduction and the amount of outer air introduction.

[0070] Consequently, the inner/outer air changeover door constitutes an air introduction amount change means for selecting an air inlet mode for the purpose of changing the ratio between the amount of inner air introduction into the casing **31** and the amount of outer air introduction into the casing **31**. More specifically, the inner/outer air changeover door is driven by an electric actuator **62** for the inner/outer air changeover door. The operation of the electric actuator **62** is controlled by a control signal output from the air-conditioning control device **50**.

[0071] Three different air inlet modes are selectable: inner air mode, outer air mode, and inner/outer air mixture mode. The inner air mode fully opens the inner air introduction port and fully closes the outer air introduction port to introduce the inner air into the casing **31**. The outer air mode fully closes the inner air introduction port and fully opens the outer air introduction port to introduce the outer air into the casing **31**. The inner/outer air mixture mode, which is an intermediate between the inner air mode and the outer air mode, continuously adjusts the opening areas of the inner and outer air introduction ports for the purpose of continuously changing the ratio between the amount of inner air introduction and the amount of outer air introduction.

[0072] The blower **32** is disposed downstream of the inner/outer air changeover box with respect to the flow of air and operated so that the air taken in through the inner/outer air changeover box is blown into the passenger compartment. The blower **32** is an electric blower that uses an electric motor to drive a multiblade centrifugal fan (sirocco fan). The rotation speed (an availability factor, that is, an operating rate) of the blower **32** is controlled by a control voltage output from the air-conditioning control device **50**. Hence, the air-conditioning control device **50** constitutes a blower control means.

[0073] The aforementioned indoor evaporator **26** is disposed downstream of the blower **32** with respect to the flow of air. In addition, air paths, such as a heating cool air path **33** for making the air flow after passing through the indoor evaporator **26** and a cool air bypass path **34**, and a mixing space **35**, which mixes the air flowing out of the heating cool air path **33** with the air flowing out of the cool air bypass path **34**, are formed downstream of the indoor evaporator **26** with respect to the flow of air.

[0074] In the heating cool air path **33**, the heater core **36**, the indoor condenser **12**, and the PTC heater **37**, which constitute a heating means for heating the air after passing through the indoor evaporator **26**, are arranged in the order named with respect to the direction of flow of blown air. The heater core **36** is connected to a cooling water piping that constitutes the cooling water circuit **40**, and acts as a heating heat exchanger that heats the air after passing through the indoor evaporator **26** by heat exchange between the cooling water (heat medium) for the engine EG and the air after passing through the indoor evaporator **26**.

[0075] The cooling water circuit **40** will now be described. The cooling water circuit **40** circulates the cooling water to cool the engine EG. The electric cooling water pump **40***a*, which pumps the cooling water, is disposed in the cooling water piping of the cooling water circuit **40**. The rotation speed (water pumping capability) of the cooling water pump **40***a* is controlled by a control voltage output from the air-conditioning control device **50**.

[0076] When the air-conditioning control device **50** operates the cooling water pump **40***a*, the cooling water, which is heated by the waste heat of the engine EG, flows into the radiator or the heater core **36**. The cooling water is then cooled by the radiator or by the heater core **36** and returns to the engine EG.

[0077] In other words, the cooling water is a heat source medium that heats the air blown into the passenger compartment by the heater core **36**. A portion of the cooling water circuit **40** that is indicated by the broken lines in FIGS. **1** to **4**, which is a circuit for circulating the cooling water from the cooling water pump **40***a* through the heater core **36** and the engine EG to the cooling water pump **40***a*, constitutes a temperature regulation means for adjusting the temperature of the blown air.

[0078] The PTC heater **37** is an electric heater that includes a PTC element (positive temperature coefficient thermistor) and serves as an auxiliary heating means. When electrical power is supplied to the PTC element, the PTC heater **37** generates heat and heats the air after passing through the indoor condenser **12**. The present embodiment uses a plurality of units of the PTC heater **37** (actually three PTC heaters). The air-conditioning control device **50** controls the overall heating capability (an availability factor, that is, an operating rate) of the PTC heater **37** by changing the number of energized units of the PTC heater **37**.

[0079] More specifically, the PTC heater **37** includes a plurality of (three in the present embodiment) PTC heaters **37***a*, **37***b*, **37***c* as shown in FIG. **6**. FIG. **5** is a circuit diagram illustrating the electrical connection of the PTC heater **37** according to the present embodiment. The electrical power consumption required for operating the PTC heater **37** according to the present embodiment is lower than required for operating the compressor **11** in the refrigeration cycle **10**.

[0080] As shown in FIG. **6**, the positive terminal side of each PTC heater **37***a*, **37***b*, **37***c* is connected to the battery **81**, whereas the negative terminal side is connected to a ground side through a respective switch element SW1, SW2, SW3 included in each PTC heater **37***a*, **37***b*, **37***c*. Each switch element SW1, SW2, SW3 switches each PTC element h1, h2, h3 included in each PTC heater **37***a*, **37***b*, **37***c* between an energized state (ON state) and a de-energized state (OFF state).

[0081] The operation of each switch element SW1, SW2, SW3 is independently controlled by a control signal output from the air-conditioning control device **50**. Hence, the air-conditioning control device **50** independently switches each switch element SW1, SW2, SW3 between the energized state and de-energized state. Consequently, the PTC heaters **37***a*, **37***b*, **37***c* can be selectively energized to exercise their heating capability to change the overall heating capability of the PTC heater **37**.

[0082] Meanwhile, the cool air bypass path **34** is an air path for directly introducing the air after passing through the indoor evaporator **26** into the mixing space **35**, bypassing the heater core **36**, the indoor condenser **12**, and the PTC heater **37**. Therefore, the temperature of the blown air mixed in the mixing space **35** varies with the ratio between the amount of air passing through the heating cool air path **33** and the amount of air passing through the cool air bypass path **34**.

[0083] As such being the case, the present embodiment uses an air mix door **38**. The air mix door **38** is disposed downstream of the indoor evaporator **26** with respect to the flow of air and toward the inlets of the heating cool air path **33** and cool air bypass path **34** to continuously vary the ratio between the amount of cool air introduced into the heating cool air path **33** and the amount of cool air introduced into the cool air bypass path **34**.

[0084] Hence, the air mix door **38** constitutes a temperature regulation means for adjusting the air temperature in the mixing space **35** (the temperature of air blown into the passenger compartment). More specifically, the air mix door **38** is driven by an electric actuator **63** for the air mix door. The operation of the electric actuator **63** is controlled by a control signal output from the air-conditioning control device **50**.

[0085] Further, air outlets **39** are disposed at the most downstream end of the casing **31** with respect to the flow of blown air. The air outlets blow the temperature-regulated blown air from the mixing space **35** into the passenger compartment, which is a cooling target space. Specifically, three different air outlets are disposed: a face air outlet, a foot air outlet, and a defroster air outlet (none of them is illustrated). The face air outlet blows air-conditioned air toward the upper body of the occupant in the passenger compartment. The foot air outlet blows the air-conditioned air toward the lower body (especially, the feet) of the occupant. The defroster air outlet blows the air-conditioned air toward the inner surface of the vehicle's windshield.

[0086] Moreover, a face door (not shown), a foot door (not shown), and a defroster door (not shown) are disposed upstream of the face air outlet, foot air outlet, and defroster air outlet, respectively, with respect to the flow of air. The face door adjusts the opening area of the face air outlet. The foot door adjusts the opening area of the foot air outlet. The defroster door adjusts the opening area of the defroster air outlet.

[0087] The face door, the foot door, and the defroster door constitute an air outlet mode selection means for selecting an air outlet mode. These doors are coupled to an electric actuator **64** for driving an air outlet mode door through a link mechanism (not shown) and rotated in conjunction with the electric actuator **64**. The operation of the electric actuator **64** is also controlled by a control signal output from the air-conditioning control device **50**. Hence, the air-conditioning control device **50** constitutes an air outlet mode selection control means.

[0088] Selectable air outlet modes are a face mode, a bi-level mode, a foot mode, and a foot/defroster mode. The face mode fully opens the face air outlet and blows air from the face air outlet toward the upper body of the occupant in the passenger compartment. The bi-level mode opens both the face air outlet and the foot air outlet and blows air toward the upper body and feet of the occupant in the passenger compartment. The foot mode fully opens the foot air outlet, opens the defroster air outlet to a small degree, and blows air mainly out of the foot air outlet. The foot/defroster mode opens the foot air outlet and defroster air outlet to the same degree and blows air out of both the foot air outlet and the defroster air outlet.

[0089] In other words, the bi-level mode is an air outlet mode in which the blown air is blown out from both of the face air outlet and the foot air outlet, and the face mode is an air outlet mode in which the proportion of the amount of the air flow blown out from the face air outlet is larger than in the bi-level mode and the proportion of the amount of the air flow blown out from the foot air outlet is smaller than in the bi-level mode.

[0090] Further, the occupant can manually operate a switch on a later-described operation panel **60** to select a defroster mode in which the defroster air outlet fully opens to blow air from the defroster air outlet toward the inner surface of the vehicle's windshield.

[0091] It should be noted that the hybrid vehicle to which the air conditioner for a vehicle **1** according to the present embodiment is applied includes an electric heating defogger (not shown) separately from the air conditioner for a vehicle. The electric heating defogger is an electric heating wire disposed in or on passenger compartment windows and used to heat the windows for the purpose of defogging the windows or preventing the windows from being fogged. The operation of the electric heating defogger can be controlled by a control signal output from the air-conditioning control device **50**.

[0092] An electrical control section according to the present embodiment will now be described with reference to FIG. **5**. The air-conditioning control device **50** includes a well-known microcomputer and its peripheral circuits, the microcomputer including, for example, a CPU, a ROM, and a RAM. In accordance with an air-conditioning control program stored in the ROM, the air-conditioning control device **50** performs various computations and processes to control the operations of various instruments connected to its output side, such as the inverter **61** of the electric motor **11***b* for the compressor **11**, the solenoid valves **13**, **17**, **20**, **21**, **24** constituting the refrigerant circuit selection means, the blower fan **16***a*, the blower **32**, and the electric actuators **62**, **63**, **64**.

[0093] The air-conditioning control device **50** is configured integrally with a control means for controlling the above-mentioned instruments. In the present embodiment, however, elements (hardware and software) for controlling the operation (refrigerant discharge capability) of the electric motor **11***b*, which is a means for changing the discharge capability of the compressor **11**, constitute a discharge capability control means **50***a*. Obviously, the discharge capability control means **50***a* may be implemented as a unit separate from the air-conditioning control device **50**.

[0094] The input side of the air-conditioning control device **50** inputs detection signals of various sensors, such as an inner air sensor **51** for detecting a passenger compartment temperature Tr, an outer air sensor **52** (outer air temperature detection means) for detecting an outer air temperature Tam, an insolation sensor **53** for detecting the amount of insolation Ts in the passenger compartment, a discharge temperature sensor **54** (discharge temperature detection means) for detecting the discharged refrigerant temperature Td of the compressor **11**, a discharge pressure sensor **55** (discharge pressure detection means) for detecting the discharge side refrigerant pressure (high-pressure side refrigerant pressure) Pd of the compressor **11**, an evaporator temperature sensor **56** (evaporator temperature detection means) for detecting a blown air temperature (evaporator temperature) Te from the indoor evaporator **26**, an intake air temperature sensor **57** for detecting the temperature Tsi of the refrigerant distributed between the first three-way joint **15** and the low-voltage solenoid valve **17**, a cooling water temperature sensor for detecting an engine cooling water temperature Tw, a humidity sensor for detecting the relative humidity of passenger compartment air near the passenger compartment windows, a window vicinity temperature sensor for detecting the temperature of the passenger compartment air near the windows, and a window surface temperature sensor for detecting the surface temperature of the windows.

[0095] In the cooling mode, the discharge side refrigerant pressure (high-pressure side refrigerant pressure) Pd of the compressor **11** according to the present embodiment is the high-pressure side refrigerant pressure of the cycle between the refrigerant discharge side of the compressor **11** and the inlet side of the variable throttle mechanism portion **27***b* for the thermostatic expansion valve **27**. In the other operation modes, the discharge side refrigerant pressure (high-pressure side refrigerant pressure) Pd of the compressor **11** according to the present embodiment is the high-pressure side refrigerant pressure of the cycle between the refrigerant discharge side of the compressor **11** and the inlet side of the fixed throttle **14**. It should be noted that the discharge pressure sensor **55** is also included in a common refrigeration cycle in order to monitor for an abnormal increase in the high-pressure side refrigerant pressure.

[0096] Specifically, the evaporator temperature sensor **56** detects the temperature of a heat exchange fin in the indoor evaporator **26**. Obviously, a temperature detection means for detecting the temperature of another part of the indoor evaporator **26** may be used as the evaporator temperature sensor **56**. A temperature detection means for directly detecting the temperature of the refrigerant flowing in the indoor evaporator **26** may also be used. Values detected by the humidity sensor, window vicinity temperature sensor, and window surface temperature sensor are used to calculate the relative humidity of a window surface RHW.

[0097] The input side of the air-conditioning control device **50** also inputs an operation signal from various air-conditioning operating switches mounted on the operation panel **60** disposed near the instrument panel at the front of the passenger compartment. The air-conditioning operating switches mounted on the operation panel **60** are, for example, an operating switch, an auto switch, an operation mode selector switch, an air outlet mode selector switch, an air flow rate setup switch for the blower **32**, a passenger compartment temperature setup switch, and an economy switch. All of these switches are used to operate the air conditioner for a vehicle **1**.

[0098] The auto switch is used to enter or exit an automatic control mode of the air-conditioner for a vehicle **1**. The passenger compartment temperature setup switch is a target temperature setup means that is operated by the occupant to set a target temperature Tset for the passenger compartment. The economy switch is a power saving request means that is turned on by the occupant to output a power saving request signal for the purpose of saving the power required for air-conditioning the passenger compartment.

[0099] Further, when the economy switch is turned on, a signal is output in the EV driving mode to the engine control device in order to decrease the frequency of the operation of the engine EG, which is operated to assist the driving electric motor.

[0100] As is the case with the air-conditioning control device **50**, the engine control device (not shown) includes a well-known microcomputer and its peripheral circuits. In accordance with an engine control program stored in the ROM, the engine control device performs various computations and processes to control the operations of various engine control instruments connected to its output side.

[0101] The output side of the engine control device is connected, for instance, to various engine components, which constitute the engine EG. More specifically, the output side of the engine control device is connected, for instance, to a starter (not shown), which starts the engine EG, and to a drive circuit (not shown) for a fuel injection valve (injector), which supplies fuel to the engine EG.

[0102] The input side of the engine control device **70** is connected to various engine control sensors, such as a voltmeter (not shown) for detecting the inter-terminal voltage VB of the battery **81**, an accelerator opening sensor (not shown) for detecting the degree of accelerator opening Acc, and an engine speed sensor (not shown) for detecting an engine speed Ne.

[0103] The air-conditioning control device **50** and the engine control device are electrically connected and capable of electrically communicating with each other. This permits one of these control devices to control the operations of instruments connected to its output side in accordance with a detection signal or operation signal input into the other control device. For example, the air-conditioning control device **50** can operate the engine EG by outputting an engine operation request signal to the engine control device.

[0104] The air-conditioning control device **50** and the engine control device are configured integrally with a control means for controlling various control target instruments connected to their output side. However, elements (hardware and software) for controlling the operation of a respective control target instrument constitute a control means for controlling the operation of the respective control target instrument.

[0105] For example, elements included in the air-conditioning control device **50** to control the refrigerant discharge capability of the compressor **11** by controlling the frequency of an AC voltage output from the inverter **61** connected to the electric motor **11*b*** for the compressor **11** constitute a compressor control means, and elements included in the air-conditioning control device **50** to control the air blowing capability of the blower **32** by controlling the operation of the blower **32**, which is an air blowing means, constitute a blower control means.

[0106] Operations of the present embodiment, which is configured as described above, will now be described with reference to FIG. **7**. FIG. **7** is a flowchart illustrating a control process performed by the air conditioner for a vehicle **1** according to the present embodiment. Even when a vehicle system is stopped, this control process is performed as far as electrical power is supplied from the battery to the air-conditioning control device **50**.

[0107] First of all, step S**1** is performed to determine whether the operating switch for the air conditioner for a vehicle **1** is turned on (ON) and whether a start switch for pre-air conditioning is turned on. If the determination result obtained in step S**1** indicates that either the operating switch for the air conditioner for a vehicle **1** or the start switch for pre-air conditioning is turned on, processing proceeds to step S**2**.

[0108] The start switch for pre-air conditioning is mounted, for instance, on a wireless terminal (remote controller) or mobile communication means (or more specifically, a cell phone) carried by the occupant. Therefore, the occupant can start the air conditioner for a vehicle **1** from a place remote from the vehicle.

[0109] When, for instance, the start switch for pre-air conditioning that is mounted on the wireless terminal is turned on, the vehicle directly receives a pre-air conditioning start signal transmitted from the wireless terminal and concludes that the start switch for pre-air conditioning is turned on. On the other hand, when the start switch for pre-air conditioning that is mounted on the mobile communication means is turned on, the vehicle directly receives a pre-air conditioning start signal transmitted, for instance, through a cell phone base station and concludes that the start switch for pre-air conditioning is turned on.

[0110] Further, the air conditioner for a vehicle **1** according to the present embodiment is applied to a plug-in hybrid vehicle. Therefore, when electrical power is supplied to the vehicle from an external power source, pre-air conditioning is continuously provided until a user of the vehicle issues a request for stopping a pre-air conditioning process. When, on the other hand, no electrical power is supplied from an external power source, pre-air conditioning is continuously provided until the amount of electrical power remaining in the battery **81** is not larger than a predetermined amount.

[0111] Step S**2** is performed to initialize, for example, a flag and a timer and returns, for example, a stepping motor, which is one of the aforementioned electric actuators, to its initial position. When the flag is to be initialized, its current status may be retained depending on the case. Processing then proceeds to step S**3**. In step S**3**, the operation signals of the operation panel **60** are read. Processing then proceeds to step S**4**. The operation signals read in step S**3** include a signal indicative of the target temperature (Tset) for the passenger compartment, an air outlet mode selection signal, an air inlet mode selection signal, and a signal for setting the amount of air supplied from the blower **32**.

[0112] In step S**4**, vehicle environmental condition signals used for air-conditioning control, namely, the signals detected by the aforementioned sensors **51**-**57** are read. Processing then proceeds to step S**5**. In step S**5**, a target blown air temperature TAO for the air blown into the passenger compartment is calculated. In the heating mode, a heating heat exchanger target temperature is also calculated. The target blown air temperature TAO is calculated from Equation F1 below.

$$TAO = Kset \times Tset - Kr \times Tr - Kam \times Tam - Ks \times Ts + C \qquad (F1)$$

where Tset is a passenger compartment temperature setting selected by the passenger compartment temperature setup switch, Tr is an inner air temperature detected by the inner air sensor **51**, Tam is an outer air temperature detected by the outer air sensor **52**, and Ts is the amount of insolation detected by the insolation sensor **53**. Kset, Kr, Kam, and Ks are control gains. C is a constant for correction.

[0113] The heating heat exchanger target temperature is basically calculated from Equation F1 above. In some cases, however, it may be calculated from Equation F1 and then corrected to be a value smaller than TAO for the purpose of reducing the amount of power consumption.

[0114] In subsequent steps S**6** to S**16**, the controlled conditions of various instruments connected to the air-conditioning control device **50** are determined. Step **6** is performed in accordance with air-conditioning environmental conditions to select the cooling mode, the heating mode, the first dehumidification mode, or the second dehumidification mode.

[0115] For example, the cooling mode should be selected when the face mode is used as an air outlet mode. The heating mode, the first dehumidification mode, or the second dehumidification mode should be selected when the inner air mode is used as an air inlet mode. Further, the heating mode, the first dehumidification mode, and the second dehumidification mode should be selectively used in accordance with the blown air temperature (evaporator temperature) Te from the indoor evaporator **26**, which is detected by the evaporator temperature sensor **56**.

[0116] More specifically, if the blown air temperature Te is higher than a first reference blown air temperature (e.g., 0° C.), the heating mode should be selected because no dehumidification is needed. If the blown air temperature Te is not higher than the first reference blown air temperature and is higher than a second reference blown air temperature (e.g., −1° C.), the first dehumidification mode should be selected because dehumidification is needed. If the blown air temperature Te is not higher than the second reference blown air temperature, the second dehumidification mode in which dehumidification takes precedence over heating should be selected.

[0117] In step S**7**, the target amount of air blown by the blower **32** is determined. More specifically, a blower motor voltage to be applied to the electric motor for the blower **32** is determined. A control process performed in step S**7** will now be described in more detail with reference to FIG. **8**. First of all, step S**701** is performed to determine whether the auto switch on the operation panel **60** is turned on.

[0118] If the determination result obtained in step S**701** does not indicate that the auto switch is turned on, processing proceeds to step S**702**. Step S**702** is performed to determine a blower motor voltage that provides an air flow rate desired by the occupant, which is set by the air flow rate setup switch on the operation panel **60**. Processing then proceeds to step S**8**. The air flow rate setup switch according to the present embodiment permits the occupant to sequentially select the Lo, M1, M2, M3, and Hi positions to specify one of five different air flow rates. Selecting the Lo, M1, M2, M3, and Hi positions in sequence gradually raises the blower motor voltage, that is, sequentially selects blower motor voltages of 4 V, 6 V, 8 V, 10 V, and 12 V.

[0119] If, on the other hand, the determination result obtained in step S**701** indicates that the auto switch is turned on, processing proceeds to step S**703**. In step S**703**, a control map stored in the air-conditioning control device **50** is referenced to determine a first tentative blower level f(TAO) in accordance with the target blown air temperature TAO determined in step S**4**. In other words, the availability factor of the blower **32** is determined based on an air-conditioning load which is a load on the air conditioner.

[0120] More specifically, the present embodiment maximizes the first tentative blower level f(TAO) in an extremely low temperature region (maximum cooling region) of the TAO and in an extremely high temperature region (maximum heating region) and exercises control to substantially maximize the air flow rate of the blower **32**. Further, if the TAO increases from the extremely low temperature region toward an intermediate temperature region, the present embodiment lowers the first tentative blower level f(TAO) in accordance with an increase in the TAO, thereby decreasing the air flow rate of the blower **32**.

[0121] Furthermore, if the TAO decreases from the extremely high temperature region toward the intermediate temperature region, the present embodiment lowers the first tentative blower level f(TAO) in accordance with a decrease in the TAO, thereby decreasing the air flow rate of the blower **32**. Moreover, if the TAO is within a predetermined intermediate temperature region, the present embodiment minimizes the first tentative blower level f(TAO) to minimize the air flow rate of the blower **32**.

[0122] In the next step, which is step S**704**, a second tentative blower level f(TW)d is determined. The second tentative blower level f(TW)d is used in the heating mode to adjust the blower level in accordance with the engine cooling water temperature Tw and with the number of energized units of the PTC heater **37**. In other words, the upper limit value of the availability factor of the blower **32** is determined based on the engine cooling water temperature Tw.

[0123] In the present embodiment, a diagram depicting the relationship between the engine cooling water temperature Tw and the second tentative blower level f(TW)d, which is shown under step S**704**, is complied with. More specifically, if the engine cooling water temperature Tw is in a low temperature region lower than a predetermined first reference temperature T1, the blower level is set to level 0 (zero), namely, the blower **32** is stopped. If, on the other hand, the engine cooling water temperature Tw is not lower than the first reference temperature T1, the second tentative blower level f(TW)d is determined in such a manner that the blower level rises in accordance with an increase in the engine cooling water temperature Tw. In other words, when the engine cooling water temperature Tw becomes equal to or larger than the first reference temperature T1, the second tentative blower level f(TW)d is determined so that the smaller the engine cooling water temperature Tw is, the further the availability factor of the blower **32** is limited.

[0124] As such being the case, the operation of the blower **32** can be stopped when the heater core **36** cannot heat the blown air because the temperature of the cooling water flowing in the heater core **36** is lower than the first reference temperature T1. This makes it possible to inhibit the occupant from feeling improperly air-conditioned as insufficiently heated air is blown toward the occupant.

[0125] If, in the above instance, the PTC heater **37** is energized, it can heat the blown air even when the engine cooling water temperature Tw is low. In step S**704**, therefore, the first reference temperature T1 is lowered in accordance with an increase in the number of energized units of the PTC heater **37**, which is determined in later-described step S**12**. In other words, the availability factor of the blower **32** is increased with an increase in the availability factor of the PTC heater **37**. As a result, the engine cooling water temperature Tw at which the blower **32** starts running decreases with an increase in the number of energized units of the PTC heater **37**.

[0126] Further, in a high temperature region in which the engine cooling water temperature Tw is not lower than the first reference temperature T1, the blower level rises at a constant rate in accordance with an increase in the engine cooling water temperature Tw no matter whether the PTC heater **37** is energized. In other words, when the engine cooling water temperature Tw is not lower than the first reference temperature T1, the degree of increase in the availability factor of the blower **32** with respect to increase in the availability factor of the PTC heater **37** is smaller than when the engine cooling water temperature Tw is lower than the first reference temperature T1.

[0127] More specifically, if the engine cooling water temperature Tw is lower than the first reference temperature T1 in a situation where the engine cooling water temperature Tw is rising, the second tentative blower level f(TW)d is set to level 0 (zero) to stop the operation of the blower **32**. In this instance, setup is performed so that the first reference temperature T1 sequentially decreases from 40° C. through 37° C. and 34° C.

to 30° C. when the number of energized units of the PTC heater **37** increases from 0 (zero) through 1 and 2 to 3.

[0128] If, on the other hand, the engine cooling water temperature Tw is not lower than the first reference temperature T1, the second tentative blower level f(TW)d is gradually increased with an increase in the engine cooling water temperature Tw without regard to the number of energized units of the PTC heater **37**. If the engine cooling water temperature Tw rises to a second reference temperature T2 (e.g., 70° C.) or higher, the second tentative blower level f(TW)d is set to a maximum value (e.g., level 30).

[0129] Meanwhile, if the engine cooling water temperature Tw is not higher than a third reference temperature T3 (e.g., 65° C.) in a situation where the engine cooling water temperature Tw is lowering, the second tentative blower level f(TW)d is gradually decreased with a decrease in the engine cooling water temperature Tw. If the engine cooling water temperature Tw is lower than a fourth reference temperature T4 and not lower than a fifth reference temperature T5, the second tentative blower level f(TW)d is set to an extremely small value (e.g., level 1).

[0130] In the above instance, setup is performed so that the fourth reference temperature T4 sequentially decreases from 36° C. through 33° C. and 30° C. to 26° C. when the number of energized units of the PTC heater **37** increases from 0 (zero) through 1 and 2 to 3. Setup is also performed so that the fifth reference temperature T5 sequentially decreases from 29° C. through 26° C. and 23° C. to 19° C. when the number of energized units of the PTC heater **37** increases from 0 (zero) through 1 and 2 to 3.

[0131] If the engine cooling water temperature Tw is lower than the fifth reference temperature T5, the second tentative blower level f(TW)d is set to level 0 (zero) to stop the operation of the blower **32**. The relationship between the first to fifth reference temperatures is such that T2>T3>T1>T4>T5. The differences between the reference temperatures are set as a hysteresis width to prevent control hunting.

[0132] The next step, which is step S**705**, is performed to determine whether the air outlet mode, which is to be determined in later-described step S**9**, is one of the foot mode, bi-level mode, and foot/defroster mode. If the determination result obtained in step S**705** indicates that the air outlet mode is one of the foot mode, bi-level mode, and foot/defroster mode, processing proceeds to step S**706**.

[0133] In step S**706**, a control map stored in the air-conditioning control device **50** beforehand is referenced to determine a third tentative blower level f(TW) based on the air outlet mode and the second tentative blower level f(TW)d that is determined in step S**704**.

[0134] More specifically, in step S**706**, the third tentative blower level f(TW) is set to be equal to the second tentative blower level f(TW)d when the air outlet mode is other than the bi-level mode. In addition, the third tentative blower level f(TW) is set to a minimum value (0 level in this example) when the air outlet mode is the bi-level mode and the second tentative blower level f(TW)d is a minimum value (0 level in this example).

[0135] In addition, the third tentative blower level f(TW) is set to a maximum value (30 level in this example) when the air outlet mode is the bi-level mode and the second tentative blower level f(TW)d is other than the minimum value (other than 0 level in this example). In other words, the upper limit value of the availability factor of the blower **32** is determined to be equal to or larger than the availability factor of the blower **32** that is determined based on the air-conditioning load.

[0136] This makes it possible, when the air outlet mode is the bi-level mode, to cancel the effect of the limitation on the availability factor of the blower **32** that is caused by the second tentative blower level f(TW)d in step S**704**. Therefore, it is possible to increase the amount of the air flow blown out from the face air outlet even if the temperature of the cooling water that flows through the heater core **36** is not sufficiently high. As a result, it is possible to improve comfort of the occupant when solar radiation is strong.

[0137] In addition, in the case that the temperature of the cooling water flowing through the heater core **36** is smaller than the first reference temperature T1 or the fifth reference temperature T5 and that it is hence impossible to heat the blown air by means of the heater core **36**, the limitation on the availability factor of the blower **32** that is caused by the second tentative blower level f(TW)d at step S**704** comes into effect even if the air outlet mode is the bi-level mode. This makes it possible to inhibit the occupant from feeling improperly air-conditioned as unheated air is blown from the foot air outlet to the feet of the occupant.

[0138] At this time, as is described in connection with step S**704**, the first reference temperature T1 and the fifth reference temperature T5 are decreased as the number of energized units of the PTC heater **37** increases. This makes it possible that the effect of the limitation on the availability factor of the blower **32** caused by the second tentative blower level f(TW)d at step S**704** is canceled at a lower engine cooling water temperature in accordance with increase of the number of energized units of the PTC heater **37** and that comfort of the occupant is hence improved when solar radiation is strong.

[0139] In step S**707**, the first tentative blower level f(TAO) determined in step S**703** is compared to the third tentative blower level f(TW) determined in step S**706**. The smaller of these two values is then determined as the current blower level, and processing proceeds to step S**708**.

[0140] In step S**708**, the control map stored in the air-conditioning control device **50** is referenced to determine the blower motor voltage in accordance with the current blower level determined in step S**707**. Processing then proceeds to step S**8**.

[0141] More specifically, if, in step S**708**, the blower level is lower than level 1, the blower motor voltage is set to a voltage of 0 V. If, on the other hand, the blower level is not lower than level 1, the blower motor voltage is increased with an increase in the blower level. If the blower level is higher than level 30, the blower motor voltage is set to a maximum voltage (12 V).

[0142] Meanwhile, if the determination result obtained in step S**705** does not indicate that the air outlet mode is one of the foot mode, bi-level mode, and foot/defroster mode, processing proceeds to step S**709**.

[0143] In step S**709**, the first tentative blower level f(TAO) determined in step S**703** is determined as the current blower level. Processing then proceeds to step S**710**. In other words, if the air outlet mode is neither the foot mode, nor the bi-level mode, nor the foot/defroster mode, that is, the heating mode is not selected, the first tentative blower level f(TAO) is determined as the current blower level without regard to the second tentative blower level f(TW)d for adjusting the blower level in the heating mode.

[0144] In step S**710**, the control map stored in the air-conditioning control device **50** is referenced to determine the blower motor voltage in accordance with the current blower level determined in step S**709**, as is the case with step S**708**. Processing then proceeds to step S**8**. The control map used in step S**710** will not be described because it is the same as the control map used in step S**708**.

[0145] In step S**8**, the air inlet mode, that is, the status of the inner/outer air changeover box, is determined. The control map stored in the air-conditioning control device **50** is also referenced to determine the air inlet mode in accordance with the TAO. In the present embodiment, the outer air mode, which introduces the outer air, is preferentially selected under normal conditions. However, if, for instance, a high cooling performance is to be provided as the TAO is in an extremely low temperature region, the inner air mode, which introduces the inner air, is selected. An alternative is to provide an exhaust gas concentration detection means for detecting the exhaust gas concentration in the outer air and select the inner air mode when the exhaust gas concentration is not lower than a predetermined reference concentration.

[0146] In step S**9**, the air outlet mode is determined. A control process performed in step S**9** will now be described in detail with reference to FIG. **9**. First of all, in step S**91**, a control map stored in the air-conditioning control device **50** is referenced to determine a correction value cc which is used at step S**92** which is described later.

[0147] More specifically, the correction value cc is determined to be a minimum level (0 in this example) when the amount of insolation is in a low insolation amount range which is smaller than a predetermined first reference value (0 W/im^2 in this example), determined to be a maximum level (10 in this example) when the amount of insolation is in a high insolation amount range which is larger than a predetermined second reference value (700 W/im^2 in this example), and determined so that the correction value cc increases in accordance with increase of the amount of insolation when the amount of insolation is equal to or larger than the first reference value and equal to or smaller than the second reference value.

[0148] In the next step S**92**, a control map stored beforehand in the air-conditioning control device **50** is referenced to determine a current air outlet mode f1(TAO) based on the TAO and the correction value α. Processing then proceeds to step S**10**

[0149] More specifically, in a situation where the TAO is increasing, the face mode is selected if the TAO≤first predetermined temperature T'1+the correction value α (e.g., 30+α° C.), the bi-level mode is selected if a first predetermined temperature T'1+the correction value α<TAO≤second predetermined temperature T'2 (e.g., 40° C.), and the foot mode is selected if the second predetermined temperature T'2<TAO.

[0150] On the other hand, in a situation where the TAO is decreasing, the foot mode is selected if a third temperature T'3 (e.g., 38° C.)≤TAO, the bi-level mode is selected if a fourth predetermined temperature T'4+the correction value α(e.g., 27+α° C.)≤TAO<third predetermined temperature T'3, and the face mode is selected if the TAO<fourth predetermined temperature T'4+the correction value α. The relationship between the first to fourth predetermined temperatures is such that T'4<T'1<T'3<T'2. The differences between the reference temperatures are set as a hysteresis width to prevent control hunting.

[0151] With this operation, in accordance with increase of the amount of the insolation, a range of an air-conditioning load in which the air outlet mode is determined to be the bi-level mode is narrowed down, and a range of an air-conditioning load in which the air outlet mode is determined to be the face mode is widened. Therefore, in accordance with increase of the amount of insolation, it becomes more unlikely that the air outlet mode is determined to be the bi-level mode, and it becomes more likely that the air outlet mode is determined to be the face mode. Therefore, it is possible to improve comfort of the occupant by increasing the amount of the air flow blown out from the face air outlet when solar radiation is strong.

[0152] In addition, since the proportion of the amount of the air flow blown out from the foot air outlet is smaller in the face mode than in the bi-level mode, it is possible to ease the occupant's feeling that his/her feet is receiving cold wind if it becomes more likely that the air outlet mode is determined to be the face mode.

[0153] In step S**10**, a target opening SW of the air mix door **38** is calculated in accordance with the TAO, with the blown air temperature Te from the indoor evaporator **26**, which is detected by the evaporator temperature sensor **56**, and with a heater temperature.

[0154] The heater temperature is a value determined in accordance with the heating capability of a heating means (heater core **36**, indoor condenser **12**, and PTC heater **37**) disposed in the heating cool air path **33**. In general, the engine cooling water temperature Tw may be used as the value of the heater temperature. Accordingly, the target opening SW can be calculated from Equation F2 below.

$$SW=[(TAO-Te)/(Tw-Te)]\times 100(\%) \quad (F2)$$

[0155] When SW=0(%), it represents a maximum cooling position of the air mix door **38**, fully opens the cool air bypass path **34**, and fully closes the heating cool air path **33**. On the other hand, when SW=100(%), it represents a maximum heating position of the air mix door **38**, fully closes the cool air bypass path **34**, and fully opens the heating cool air path **33**.

[0156] In step S**11**, the refrigerant discharge capability of the compressor **11** (or more specifically, the rotation speed of the compressor **11**) is determined. A basic method of determining the rotation speed of the compressor **11** will now be described. In the cooling mode, for example, the control map stored in the air-conditioning control device **50** is referenced to determine a target blown air temperature TEO for the blown air temperature Te from the indoor evaporator **26** in accordance, for instance, with the TAO determined in step S**4**.

[0157] Next, the deviation En (TEO−Te) between the target blown air temperature TEO and the blown air temperature Te is calculated. A deviation change rate Edot (En−(En−1)) is then determined by subtracting a previously calculated deviation En−1 from the currently calculated deviation En. The deviation change rate Edot (En−(En−1)) is eventually used to determine the amount of rotation speed change Δf_C from a previous compressor rotation speed fCn−1 in accordance with a fuzzy inference based on membership functions and rules stored in the air-conditioning control device **50**.

[0158] Further, in the heating mode, in the first dehumidification mode, and in the second dehumidification mode, the control map stored in the air-conditioning control device **50** is referenced to determine a target high pressure PDO for the discharge side refrigerant pressure (high-pressure side refrigerant pressure) Pd in accordance, for instance, with the heating heat exchanger target temperature determined in step **S4**.

[0159] Next, the deviation Pn (PDO−Pd) between the target high pressure PDO and the discharge side refrigerant pressure Pd is calculated. A deviation change rate Pdot (Pn−(Pn−1)) is then determined by subtracting a previously calculated deviation Pn−1 from the currently calculated deviation Pn. The deviation change rate Pdot (Pn−(Pn−1)) is eventually used to determine the amount of rotation speed change Δf_H from a previous compressor rotation speed fHn−1 in accordance with a fuzzy inference based on the membership functions and rules stored in the air-conditioning control device **50**.

[0160] A control process performed in step S**11** will now be described in more detail with reference to FIG. **10**. First of all, in step S**111**, the amount of rotation speed change Δf_C in the cooling mode (COOL cycle) is determined. A fuzzy rule table, which is used as a set of rules, is shown under step S**111** of FIG. **10**. This rule table determines the Δf_C in such a manner as to prevent frost formation on the indoor evaporator **26** in accordance with the aforementioned deviation En and deviation change rate Edot.

[0161] In step S**112**, the amount of rotation speed change Δf_H in the heating mode (HOT cycle), in the first dehumidification mode (DRY_EVA cycle), and in the second dehumidification mode (DRY_ALL cycle) is determined. A fuzzy rule table, which is used as a set of rules, is shown under step S**112** of FIG. **10**. This rule table determines the Δf_H in such a manner as to avoid an abnormal increase in the high-pressure side refrigerant pressure Pd in accordance with the aforementioned deviation Pn and deviation change rate Pdot.

[0162] The next step, which is step S**113**, is performed to determine whether the operation mode determined in step S**6** is the cooling mode. If the determination result obtained in step S**113** indicates that the operation mode determined in step S**6** is the cooling mode, processing proceeds to step S**114**. In step S**114**, the amount of rotation speed change Δf in the compressor **11** is determined as the Δf_C. Processing then proceeds to step S**116**.

[0163] If, on the other hand, the determination result obtained in step S**113** does not indicate that the operation mode determined in step S**6** is the cooling mode, processing proceeds to step S**115**. In step S**115**, the amount of rotation speed change Δf in the compressor **11** is determined as the Δf_H. Processing then proceeds to step S**116**.

[0164] In step S**116**, the amount of rotation speed change Δf is added to a previous compressor rotation speed fn−1. The resultant value is determined as the current compressor rotation speed fn. Processing then proceeds to step S**12**. A tentative compressor rotation speed determination in step S**116** is not performed on every control cycle τ, but is performed at predetermined control intervals (at 1-second intervals in the present embodiment).

[0165] In step S**12**, the number of energized units of the PTC heater **37** and the operating status of the electric heating defogger are determined. If, for instance, the heating heat exchanger target temperature is not obtained even when the target opening SW for the air mix door **38** is 100% in the heating mode in a situation where the PTC heater needs to be energized in step S**6**, the number of energized units of the PTC heater **37** should be determined in accordance with the difference between the inner air temperature Tr and the heating heat exchanger target temperature.

[0166] Further, if it is highly probable that the windows will be fogged due to the humidity and temperature in the passenger compartment or if the windows are fogged, the electric heating defogger is energized.

[0167] In step S**13**, the operating status of each solenoid valve **13**-**24**, which is the refrigerant circuit selection means, is determined in accordance with the operation mode determined in step S**6**.

[0168] More specifically, if the cooling mode is determined as the operation mode, all the solenoid valves are de-energized as indicated in the table of FIG. **11**. If the heating mode is determined as the operation mode, the electric three-way valve **13**, the high-voltage solenoid valve **20**, and the low-voltage solenoid valve **17** are energized, whereas the remaining solenoid valves **21**, **24** are de-energized.

[0169] If the first dehumidification mode is determined as the operation mode, the electric three-way valve **13**, the low-voltage solenoid valve **17**, the dehumidification solenoid valve **24**, and the heat exchanger shut-off solenoid valve **21** are energized, whereas the high-voltage solenoid valve **20** are de-energized. If the second dehumidification mode is determined as the operation mode, the electric three-way valve **13**, the low-voltage solenoid valve **17**, and the dehumidification solenoid valve **24** are energized, whereas the remaining solenoid valves **20**, **21** are de-energized.

[0170] In other words, the present embodiment is configured so as to shut off the power supply to at least one of the solenoid valves **13**-**24** no matter what operation mode is selected for refrigerant circuit selection purposes. This makes it possible to reduce the total power consumption of the solenoid valves **13**-**24** according to the present embodiment.

[0171] In step S**14**, the air-conditioning control device **50** outputs control signals and control voltages to various instruments **61**, **13**, **17**, **20**, **21**, **24**, **16***a*, **32**, **62**, **63**, **64** in order to provide the controlled conditions determined in steps S**6** to S**13**. For example, a control signal is output to the inverter **61** of the electric motor **11***b* for the compressor **11** so that the rotation speed of the compressor **11** coincides with the rotation speed determined in step S**11**.

[0172] Next, step S**15** is performed to wait for a control cycle T. When the control cycle τ is found to have elapsed, processing proceeds to step S**16**. In the present embodiment, it is assumed that the control cycle τ is 250 ms. The reason is that passenger compartment air-conditioning control is not adversely affected even if it is exercised on a slower control cycle than, for example, engine control. In addition, the amount of communication for passenger compartment air-conditioning control can be restricted to provide an adequate amount of communication for an engine control system or other control system that has to exercise high-speed control.

[0173] If overcharging occurs due to excessive power supply from an external source in a situation where the employed vehicle is a plug-in hybrid vehicle according to the present embodiment or other vehicle that can use the battery **81** to store electrical power supplied from the external power source, a problem occurs with the battery **81** as it generates heat, emits smoke, ignites, or deteriorates. To avoid such a problem, the engine control device controls the amount of electrical power to be supplied from the external power source in compliance with a request, that is, the amount of the electrical power to be supplied from the external power source in accordance, for instance, with a detection signal generated from a wattmeter for detecting the amount of electrical power supplied from the external power source.

[0174] Further, if overdischarging occurs due to excessive power consumption of the electrically-operated instruments

11, **16***a*, **32**, **40***a* of the air condition for a vehicle **1**, a problem occurs with the battery **81** as it shortens its useful life even when electrical power is supplied from the external power source. As such being the case, the air-conditioning control device **50** according to the present embodiment performs step S**16** to output a signal to the engine control device to change its requested electrical power when the air conditioner for a vehicle **1** is operated while electrical power is supplied from the external power source.

[0175] As the air conditioner for a vehicle **1** according to the present embodiment is controlled as described above, it operates as described below depending on the operation mode selected in control step S**6**.

(a) Cooling Mode (COOL Cycle; See FIG. 1)

[0176] In the cooling mode, the air-conditioning control device **50** de-energizes all the solenoid valves. Therefore, the electric three-way valve **13** connects the refrigerant outlet side of the indoor condenser **12** to one refrigerant inflow outlet of the first three-way joint **15**. Further, the low-voltage solenoid valve **17** closes, the high-voltage solenoid valve **20** opens, the heat exchanger shut-off solenoid valve **21** opens, and the dehumidification solenoid valve **24** closes.

[0177] Hence, a vapor compression type refrigeration cycle is formed as indicated by the arrows in FIG. **1** so that the refrigerant sequentially circulates from the compressor **11** through the indoor condenser **12**, the electric three-way valve **13**, the first three-way joint **15**, the outdoor heat exchanger **16**, the second three-way joint **19**, the high-voltage solenoid valve **20**, the second check valve **22**, the variable throttle mechanism portion **27***b* of the thermostatic expansion valve **27**, the fourth three-way joint **25**, the indoor evaporator **26**, the thermosensitive portion **27***a* of the thermostatic expansion valve **27**, the fifth three-way joint **28**, and the accumulator **29** to the compressor **11**.

[0178] In the above-described refrigerant circuit in the cooling mode, the refrigerant flowing from the electric three-way valve **13** to the first three-way joint **15** does not flow toward the low-voltage solenoid valve **17** because the low-voltage solenoid valve **17** is closed. Further, the refrigerant flowing from the outdoor heat exchanger **16** to the second three-way joint **19** does not flow toward the heat exchanger shut-off solenoid valve **21** because the dehumidification solenoid valve **24** is closed. Furthermore, the refrigerant flowing out of the variable throttle mechanism portion **27***b* of the thermostatic expansion valve **27** does not flow toward the dehumidification solenoid valve **24** because the dehumidification solenoid valve **24** is closed. Moreover, the refrigerant flowing from the thermosensitive portion **27***a* of the thermostatic expansion valve **27** to the fifth three-way joint **28** does not flow toward the second check valve **22** because of an action performed by the second check valve **22**.

[0179] Consequently, the refrigerant compressed by the compressor **11** is cooled by heat exchange with the blown air (cool air) after passing through the indoor evaporator **26**, forwarded to the outdoor heat exchanger **16**, further cooled by heat exchange with the outer air, and decompressed and expanded by the thermostatic expansion valve **27**. The low-pressure refrigerant, which is decompressed by the thermostatic expansion valve **27**, flows into the indoor evaporator **26**, and evaporates as it absorbs heat from the air blown from the blower **32**. In this manner, the blown air passing through the indoor evaporator **26** is cooled.

[0180] In the above instance, the opening of the air mix door **38** is adjusted as mentioned earlier. Therefore, part (or whole) of the blown air cooled by the indoor evaporator **26** flows from the cool air bypass path **34** into the mixing space **35**. Further, part (or whole) of the blown air cooled by the indoor evaporator **26** flows into the heating cool air path **33**, becomes reheated when it passes through the heater core **36**, the indoor condenser **12**, and the heater core **36**, and then flows into the mixing space **35**.

[0181] Consequently, the temperature of the air to be blown into the passenger compartment after being mixed in the mixing space **35** is adjusted to a desired level for cooling the passenger compartment. The cooling mode excels in the capability of dehumidifying the blown air, but hardly delivers a heating capability.

[0182] The refrigerant flowing out of the indoor evaporator **26** flows into the accumulator **29** through a thermosensitive portion **27***a* of the thermostatic expansion valve **27**. A gas-phase refrigerant, which is derived from gas-liquid separation in the accumulator **29**, is taken into the compressor **11** and compressed again.

[0183] In the above-described refrigerant circuit in the cooling mode, two separate portions in the refrigerant flow path within the refrigeration cycle **10** are in communication with each other as is obvious from FIG. **1**. In other words, a lockout circuit, which does not communicate with a separate portion in the refrigerant flow path within the refrigeration cycle **10**, is not formed in the refrigerant circuit in the cooling mode.

(b) Heating Mode (HOT Cycle; See FIG. 2)

[0184] In the heating mode, the air-conditioning control device **50** energizes the electric three-way valve **13**, the high-voltage solenoid valve **20**, and the low-voltage solenoid valve **17**, and de-energizes the remaining solenoid valves **21**, **24**. Therefore, the electric three-way valve **13** connects the refrigerant outlet side of the indoor condenser **12** to the refrigerant inlet side of the fixed throttle **14**. Further, the low-voltage solenoid valve **17** opens, the high-voltage solenoid valve **20** closes, the heat exchanger shut-off solenoid valve **21** opens, and the dehumidification solenoid valve **24** closes.

[0185] Hence, a vapor compression type refrigeration cycle is formed as indicated by the arrows in FIG. **2** so that the refrigerant sequentially circulates from the compressor **11** through the indoor condenser **12**, the electric three-way valve **13**, the fixed throttle **14**, the third three-way joint **23**, the heat exchanger shut-off solenoid valve **21**, the second three-way joint **19**, the outdoor heat exchanger **16**, the first three-way joint **15**, the low-voltage solenoid valve **17**, the first check valve **18**, the fifth three-way joint **28**, and the accumulator **29** to the compressor **11**.

[0186] In the above-described refrigerant circuit in the heating mode, the refrigerant flowing from the fixed throttle **14** to the third three-way joint **23** does not flow toward the dehumidification solenoid valve **24** because the dehumidification solenoid valve **24** is closed. Further, the refrigerant flowing from the heat exchanger shut-off solenoid valve **21** to the second three-way joint **19** does not flow toward the high-voltage solenoid valve **20** because the high-voltage solenoid valve **20** is closed. Furthermore, the refrigerant flowing from the outdoor heat exchanger **16** to the first three-way joint **15** does not flow toward the electric three-way valve **13** because the electric three-way valve **13** is connected between the refrigerant outlet side of the indoor condenser **12** and the refrigerant inlet side of the fixed throttle **14**. Moreover, the refrigerant flowing from the first check valve **18** to the fifth three-way joint **28** does not flow toward the thermostatic expansion valve **27** because the dehumidification solenoid valve **24** is closed.

[0187] Consequently, the refrigerant compressed by the compressor **11** is cooled in the indoor condenser **12** by heat exchange with the blown air supplied from the blower **32**. Hence, the blown air passing through the indoor condenser **12** is heated. In this instance, the opening of the air mix door **38** is adjusted. Therefore, as is the case with the cooling mode, the temperature of the air to be blown into the passenger compartment after being mixed in the mixing space **35** is adjusted to a desired level for heating the passenger compartment. The heating mode does not exercise a function of dehumidifying the blown air.

[0188] The refrigerant flowing out of the indoor condenser **12** flows into the outdoor heat exchanger **16** after being decompressed by the fixed throttle **14**. The refrigerant flowing into the outdoor heat exchanger **16** evaporates as it absorbs heat from the outer air that is blown from the outside of the passenger compartment by the blower fan **16***a*. The refrigerant flowing out of the outdoor heat exchanger **16** flows into the accumulator **29** through the low-voltage solenoid valve **17**, the first check valve **18**, and the like. A gas-phase refrigerant, which is derived from gas-liquid separation in the accumulator **29**, is taken into the compressor **11** and compressed again.

(c) First Dehumidification Mode (DRY_EVA Cycle; See FIG. 3)

[0189] In the first dehumidification mode, the air-conditioning control device **50** energizes the electric three-way valve **13**, the low-voltage solenoid valve **17**, the heat exchanger shut-off solenoid valve **21**, and the dehumidification solenoid valve **24**, and de-energizes the high-voltage solenoid valve **20**. Therefore, the electric three-way valve **13** connects the refrigerant outlet side of the indoor condenser **12** to the refrigerant inlet side of the fixed throttle **14**. Further, the low-voltage solenoid valve **17** opens, the high-voltage solenoid valve **20** opens, the heat exchanger shut-off solenoid valve **21** closes, and the dehumidification solenoid valve **24** opens.

[0190] Hence, a vapor compression type refrigeration cycle is formed as indicated by the arrows in FIG. **3** so that the refrigerant sequentially circulates from the compressor **11** through the indoor condenser **12**, the electric three-way valve **13**, the fixed throttle **14**, the third three-way joint **23**, the dehumidification solenoid valve **24**, the fourth three-way joint **25**, the indoor evaporator **26**, the thermosensitive portion **27***a* of the thermostatic expansion valve **27**, the fifth three-way joint **28**, and the accumulator **29** to the compressor **11**.

[0191] In the above-described refrigerant circuit in the first dehumidification mode, the refrigerant flowing from the fixed throttle **14** to the third three-way joint **23** does not flow toward the heat exchanger shut-off solenoid valve **21** because the heat exchanger shut-off solenoid valve **21** is closed. Further, the refrigerant flowing from the dehumidification solenoid valve **24** to the fourth three-way joint **25** does not flow toward the variable throttle mechanism portion **27***b* of the thermostatic expansion valve **27** because of an action performed by the second check valve **22**. Furthermore, the refrigerant flowing from the thermosensitive portion **27***a* of the thermostatic expansion valve **27** to the fifth three-way joint **28** does not flow toward the first check valve **18** because of an action performed by the first check valve **18**.

[0192] Consequently, the refrigerant compressed by the compressor **11** is cooled in the indoor condenser **12** by heat exchange with the blown air (cool air) after passing through the indoor evaporator **26**. This ensures that the blown air passing through the indoor condenser **12** is heated. The refrigerant flowing out of the indoor condenser **12** flows into the indoor evaporator **26** after being decompressed by the fixed throttle **14**.

[0193] The low-pressure refrigerant flowing into the indoor evaporator **26** evaporates as it absorbs heat from the air blown from the blower **32**. This ensures that the blown air passing through the indoor evaporator **26** is cooled and dehumidified. Therefore, the blown air cooled and dehumidified by the indoor evaporator **26** is heated again when it passes through the heater core **36**, the indoor condenser **12**, and the heater core **36**, and is blown out of the mixing space **35** into the passenger compartment. In other words, the passenger compartment can be dehumidified. The first dehumidification mode can exercise a function of dehumidifying the blown air, but has a limited heating capability.

[0194] The refrigerant flowing out of the indoor evaporator **26** flows into the accumulator **29** through the thermosensitive portion **61***a* of the thermostatic expansion valve **27**. A gas-phase refrigerant, which is derived from gas-liquid separation in the accumulator **29**, is taken into the compressor **11** and compressed again.

(d) Second Dehumidification Mode (DRY_ALL Cycle; See FIG. 4)

[0195] In the second dehumidification mode, the air-conditioning control device **50** energizes the electric three-way valve **13**, the low-voltage solenoid valve **17**, and the dehumidification solenoid valve **24**, and de-energizes the remaining solenoid valves **20**, **21**. Therefore, the electric three-way valve **13** connects the refrigerant outlet side of the indoor condenser **12** to the refrigerant inlet side of the fixed throttle **14**. Further, the low-voltage solenoid valve **17** opens, the high-voltage solenoid valve **20** opens, the heat exchanger shut-off solenoid valve **21** opens, and the dehumidification solenoid valve **24** opens.

[0196] Hence, a vapor compression type refrigeration cycle is formed as indicated by the arrows in FIG. **4** so that the refrigerant sequentially circulates from the compressor **11** through the indoor condenser **12**, the electric three-way valve **13**, the fixed throttle **14**, the third three-way joint **23**, the heat exchanger shut-off solenoid valve **21**, the second three-way joint **19**, the outdoor heat exchanger **16**, the first three-way joint **15**, the low-voltage solenoid valve **17**, the first check valve **18**, the fifth three-way joint **28**, and the accumulator **29** to the compressor **11**, and that the refrigerant also sequentially circulates from the compressor **11** through the indoor condenser **12**, the electric three-way valve **13**, the fixed throttle **14**, the third three-way joint **23**, the dehumidification solenoid valve **24**, the fourth three-way joint **25**, the indoor evaporator **26**, the thermosensitive portion **27***a* of the thermostatic expansion valve **27**, the fifth three-way joint **28**, and the accumulator **29** to the compressor **11**.

[0197] In other words, in the second dehumidification mode, the refrigerant flowing from the fixed throttle **14** to the third three-way joint **23** flows toward the heat exchanger shut-off solenoid valve **21** and toward the dehumidification solenoid valve **24**. Further, the refrigerant flowing from the first check valve **18** to the fifth three-way joint **28** and the refrigerant flowing from the thermosensitive portion **27***a* of the thermostatic expansion valve **27** to the fifth three-way joint **28** converge at the fifth three-way joint **28** and flow toward the accumulator **29**.

[0198] In the above-described refrigerant circuit in the second dehumidification mode, the refrigerant flowing from the outdoor heat exchanger **16** to the first three-way joint **15** does not flow toward the electric three-way valve **13** because the electric three-way valve **13** is connected between the refrigerant outlet side of the indoor condenser **12** and the refrigerant inlet side of the fixed throttle **14**. Further, the refrigerant flowing from the dehumidification solenoid valve **24** to the fourth three-way joint **25** does not flow toward the variable throttle mechanism portion **27***b* of the thermostatic expansion valve **27** because of an action performed by the second check valve **22**.

[0199] Consequently, the refrigerant compressed by the compressor **11** is cooled in the indoor condenser **12** by heat exchange with the blown air (cool air) after passing through the indoor evaporator **26**. This ensures that the blown air passing through the indoor condenser **12** is heated. The refrigerant flowing out of the indoor condenser **12** is decompressed by the fixed throttle **14**. The decompressed refrigerant then branches at the third three-way joint **23** and flows into the outdoor heat exchanger **16** and into the indoor evaporator **26**.

[0200] The refrigerant flowing into the outdoor heat exchanger **16** evaporates as it absorbs heat from the outer air that is blown from the outside of the passenger compartment by the blower fan **16***a*. The refrigerant flowing out of the outdoor heat exchanger **16** flows into the fifth three-way joint **28** through the low-voltage solenoid valve **17**, the first check valve **18**, and the like. The low-pressure refrigerant flowing into the indoor evaporator **26** evaporates as it absorbs heat from the air blown from the blower **32**. This ensures that the blown air passing through the indoor evaporator **26** is cooled and dehumidified.

[0201] Consequently, the blown air cooled and dehumidified by the indoor evaporator **26** is heated again when it passes through the heater core **36**, the indoor condenser **12**, and the heater core **36**, and is blown out of the mixing space **35** into the passenger compartment. In this instance, the second dehumidification mode differs from the first dehumidification mode in that the former enables the indoor condenser **12** to release the heat absorbed by the outdoor heat exchanger **16**. Therefore, the second dehumidification mode can heat the blown air to a higher temperature than the first dehumidification mode. In other words, the second dehumidification mode can provide dehumidification and heating at a time, that is, deliver a dehumidification capability while delivering a high heating capability.

[0202] Further, the refrigerant flowing out of the indoor evaporator **26** flows into the fifth three-way joint **28**, joins with the refrigerant flowing out of the outdoor heat exchanger **16**, and flows into the accumulator **29**. A gas-phase refrigerant, which is derived from gas-liquid separation in the accumulator **29**, is taken into the compressor **11** and compressed again.

[0203] Furthermore, as described above, each of the refrigerant circuit in the cooling mode, the refrigerant circuit in the heating mode, and the refrigerant circuit in the first dehumidification mode may be expressed as a refrigerant circuit in a single heat exchanger mode in which the refrigerant taken into the compressor **11** is distributed to either the outdoor heat exchanger **16** or the indoor heat exchanger (or more specifically, the indoor condenser **12** and the indoor evaporator **26**). On the other hand, the refrigerant circuit in the second dehumidification mode may be expressed as a refrigerant circuit in a complex heat exchanger mode in which the refrigerant taken into the compressor **11** is distributed to both the outdoor heat exchanger **16** and the indoor heat exchanger (or more specifically, the indoor evaporator **26**).

[0204] As the air conditioner for a vehicle according to the present embodiment operates as described above, it provides the following advantages.

[0205] First, as is described in connection with control step S7 (more specifically, step S**704**), the blower **32** starts operating at a lower engine cooling water temperature Tw as the number of energized units of the PTC heater **37** increases.

[0206] Therefore, the PTC heater **37** can heat the blown air even if lowness of the engine cooling water temperature Tw causes insufficient heating of the blown air at the heater core **36**. Therefore, it is possible to early blow out the blown air that is heated by the PTC heater **37** to the occupant without waiting for increase of the engine cooling water temperature Tw. It is hence possible to improve quickness in passenger-compartment air-conditioning (heating).

[0207] In addition, it is possible to blow out the blown air which is sufficiently heated by the PTC heater **37** to the occupant even if the engine cooling water temperature Tw is low. Therefore, it is possible to reduce frequency of engine operation that is intended for passenger-compartment air-conditioning (heating) and accordingly to save fuel consumption.

[0208] There may be a problem as follows. If the availability factor of the blower **32** increases too much, in other words, if the amount of air flow from the blower **32** increases too much, heat quantity which is lost from the engine cooling water in the heater core **36** increases and so does energy which is necessary to increase the engine cooling water.

[0209] In the present embodiment, as a measure to this problem, when the temperature becomes equal to or larger than the first reference temperature T1, the degree of increase in the availability factor of the blower **32** with respect to increase in the availability factor of the PTC heater **37** becomes smaller than when the engine cooling water temperature Tw is lower than the first reference temperature T1. With this operation, it is possible to prevent the amount of air flow from the blower **32** from increasing too much by limiting the availability factor of the blower **32** when the engine cooling water temperature Tw is high. Therefore, it is possible to reduce increase of heat quantity which is lost from the engine cooling water and the energy which is necessary to increase the engine cooling water. It is hence possible to reduce energy consumption of the air conditioning. This is very advantageous in practical use of a hybrid vehicle because it is possible to decrease it is possible to reduce frequency of engine operation that is intended for the air-conditioning (heating) and accordingly to save fuel consumption.

[0210] Furthermore, the air conditioner in the present embodiment exhibits the following prominent advantage.

[0211] First, as is described in connection with control step S**706**, the limitation on the availability factor of the blower **32** is relaxed when the air outlet mode is bi-level mode. Therefore, it is possible to increase the amount of the air flow blown out from the face air outlet even if the temperature of the cooling water that flows through the heater core **36** is not sufficiently high. As a result, it is possible to improve comfort of the occupant when solar radiation is strong.

[0212] Next, as is described in connection with control step S**706**, when the engine cooling water temperature is smaller than a certain preset temperature (the first reference temperature T1 or the fifth reference temperature T5 in this example), the limitation on the availability factor of the blower **32** is not relaxed even if the air outlet mode is the bi-level mode. Therefore, it is possible to prevent the amount of the air flow blown out from the foot air outlet from increasing and to accordingly ease the occupant's feeling that his/her feet is receiving cold wind when the blown air temperature is very low.

[0213] Next, as is described in connection with control steps S**704** and S**706**, the certain preset temperature (the first reference temperature T1 or the fifth reference temperature T5 in this example) is smaller when the PTC heater **37** is operating than when the PTC heater **37** is not operating. Therefore, it is possible to relax the limitation on the availability factor of the blower **32** when the PTC heater **37** is operating even if the engine cooling water temperature is low. In addition, when the PTC heater **37** is operating, it is possible to increase the blown air temperature even if the engine cooling water temperature is low. Therefore, the occupant's feeling that his/her feet are receiving cold wind is eased. As a result, it is possible to improve, when solar radiation is strong, comfort of the occupant without harming the occupant's feeling that he/she is in a warmed room.

[0214] Next, as is described in connection with control step S**92**, in accordance with increase of the amount of insolation, it becomes more unlikely that the air outlet mode is determined to be the bi-level mode, and it becomes more likely that the air outlet mode is determined to be the face mode. Therefore, it is possible to improve comfort of the occupant by increasing the amount of the air flow blown out from the face air outlet when solar radiation is strong.

[0215] In addition, since the proportion of the amount of the air flow blown out from the foot air outlet is smaller in the face mode than in the bi-level mode, it is possible to ease the occupant's feeling that his/her feet is receiving cold wind if it becomes more likely that the air outlet mode is determined to be the face mode.

Second Embodiment

[0216] The refrigeration cycle **10** employed in the foregoing embodiment is configured so that the refrigerant circuits for the cooling mode, the heating mode, the first dehumidification mode, and the second dehumidification mode can be selectively used. However, the refrigeration cycle **10** used in the present embodiment of the present invention does not have a function for selecting various refrigerant circuits, as shown in FIG. **12**.

[0217] More specifically, the refrigeration cycle **10** according to the present embodiment is formed by circularly connecting the compressor **11**, the outdoor heat exchanger **16**, the thermostatic expansion valve **27**, and the indoor evaporator **26** in the order named. The refrigeration cycle **10** according to the present embodiment functions to cool the air to be blown into the passenger compartment from the blower. In other words, the refrigeration cycle **10** according to the present embodiment is configured to be capable of providing the cooling mode of the foregoing embodiment.

[0218] Accordingly, the refrigeration cycle **10** according to the present embodiment does not include the solenoid valves **13**-**24** that act as the refrigerant circuit selection means. Further, the refrigeration cycle **10** according to the present embodiment does not include the accumulator **29** that is connected to the refrigerant inlet of the compressor **11**. Instead, the refrigeration cycle **10** according to the present embodiment includes a receiver **29***a* that acts as a high-pressure side gas-liquid separator that receives the refrigerant from the outdoor heat exchanger **16**, separates the received refrigerant into a gas and a liquid, and stores an excess refrigerant. The other elements are the same as those of the first embodiment.

[0219] In FIG. **12**, the face air outlet **39***a*, the foot air outlet **39***b*, the defroster air outlet **39***c*, the face door **39***d*, the foot door **39***e*, and the defroster door **39***f* are illustrated which are not illustrated in FIGS. **1** to **4**.

[0220] The operation of the present embodiment is basically performed in accordance with the flowchart of FIG. **7**, which depicts the first embodiment. However, as the present embodiment does not include the solenoid valves **13**-**24** that act as the refrigerant circuit selection means, steps, for example, S**6** and S**13**, which are performed to exercise control concerning refrigerant circuit selection, are not exercised in the present embodiment. Further, step, for example, step S**112** of FIG. **10**, which depicts the first embodiment and is performed to exercise control concerning an operation mode other than the cooling mode, is not exercised in the present embodiment.

[0221] Furthermore, for example, control step S**113** of FIG. **10**, which depicts the first embodiment and is performed to determine whether the selected operation mode is the cooling mode, is not performed in the present embodiment. More specifically, control step S**113** of FIG. **10**, for example, need not be performed. Alternatively, step S**113** may be performed to constantly determine that the selected operation mode is the cooling mode.

[0222] Consequently, even when the control aspect described in conjunction with the foregoing embodiments is applied to the air conditioner for a vehicle **1** according to the present embodiment whose refrigeration cycle **10** is specially configured to provide the cooling mode for cooling the air to be blown into the passenger compartment from the blower, the present embodiment provides the same advantages as the foregoing embodiment.

Other Embodiments

[0223] The present invention is not limited to the above-described embodiments. Various modifications may be made as described below without departure from the spirit of the invention.

[0224] (1) In the first embodiment, it is described that the third tentative blower level f(TW) is set to the maximum value (30 level in this example) when the air outlet mode is the bi-level mode and the second tentative blower level f(TW)d is other than the minimum value (other than 0 level in this example), and that the effect of the limitation on the availability factor of the blower **32** is accordingly cancelled. Alternatively, however, the third tentative blower level f(TW) may be set to a value that is smaller than the maximum value and larger than the first tentative blower level f(TAO) so as to relax the limitation on the availability factor of the blower **32**.

[0225] (2) The first embodiment uses the refrigeration cycle **10** that changes the refrigerant circuit as needed to heat or cool the blown air to be supplied to the passenger compartment. The second embodiment uses the refrigeration cycle **10** that cools the blown air. Obviously, an alternative is to employ a heat pump cycle that heats the blown air by using a radiator for dissipating the heat of the refrigerant discharged from the compressor **11** as an indoor heat exchanger and by using an evaporator for evaporating the refrigerant as an outdoor heat exchanger.

[0226] (3) As regards the first to third embodiments, the driving force for running the plug-in hybrid vehicle has not been described in detail. However, the air conditioner for a vehicle **1** is applicable to both a parallel hybrid vehicle and a serial hybrid vehicle. The parallel hybrid vehicle can run by directly acquiring the driving force from both the engine EG and the driving electric motor. The serial hybrid vehicle uses the engine EG as a driving source for the generator **80**, stores the generated electrical power in the battery **81**, supplies the electrical power stored in the battery **81** to the driving electric motor, and runs by acquiring the driving force from the driving electric motor.

[0227] The air conditioner for a vehicle **1** can also be applied to an electric vehicle that does not include the engine EG and acquires the vehicle driving force from only the driving electric motor.

LIST OF REFERENCE SIGNS

[0228] **32** . . . Blower

[0229] **36** . . . Heater core (heating heat exchanger)

[0230] **50** . . . Control means

[0231] **37** . . . PTC heater (auxiliary heating means)

[0232] **39***a* . . . Face air outlet

[0233] **39***b* . . . Foot air outlet

[0234] **39***d* . . . Face door (air outlet mode switching means)

[0235] **39***e* . . . Foot door (air outlet mode switching means)

1. An air conditioner for a vehicle, comprising:

a blower that generates blown air;

a heating heat exchanger that heats the blown air by heat exchange between the blown air and a heat medium;

a control device that determines the availability factor of the blower; and

an air outlet mode switching device that switches between a plurality of air outlet modes by switching proportions of air flow blown out from a plurality of outlets which includes a face air outlet that blows out the blown air to an upper body of an occupant and a foot air outlet that blows out the blown air to a lower body of an occupant, wherein

the control device:

limits the availability factor of the blower based on a temperature of the heat medium; and

relaxes limitation on the availability factor of the blower when the air outlet mode is a bi-level mode in which the blown air is blown out from both of the face air outlet and the foot air outlet.

2. The air conditioner for the vehicle according to claim **1**, wherein the control device:

determines the availability factor of the blower based on an air-conditioning load;

determines an upper limit of the availability factor based on the temperature of the heat medium;

limits the availability factor of the blower so that the availability factor of the blower is equal to or smaller than the upper limit when the air outlet mode is a mode in which the blown air is blown out at least from the foot air outlet; and

determines the upper limit to be equal to or larger than the availability factor of the blower that is determined based on the air-conditioning load when the air outlet mode is the bi-level mode.

3. The air conditioner for the vehicle according to claim **1**, wherein the control device does not relax the limitation on the availability factor of the blower when the engine cooling water temperature is smaller than a certain temperature even if the air outlet mode is the bi-level mode.

4. The air conditioner for the vehicle according to claim **3**, comprising:

an auxiliary heating device that heats the blown air,

wherein the control device sets the certain temperature so that the certain temperature is smaller when the auxiliary heating device is operating than when the auxiliary heating device is not operating.

5. The air conditioner for the vehicle according to claim **1**, wherein the control device:

limits the availability factor of the blower based on the temperature of the heat medium when the air outlet mode is the bi-level mode;

when the air outlet mode is a face mode in which the blown air is blown out from the face air outlet, reduces limitation on the availability factor of the blower compared to when in the bi-level mode; and

controls the air outlet mode so that, in accordance with increase of an amount of insolation, it becomes more unlikely that the air outlet mode is determined to be the bi-level mode, and it becomes more likely that the air outlet mode is determined to be the face mode.

6. An air conditioner for a vehicle, comprising:

a blower that generates blown air;

a heating heat exchanger that heats the blown air by heat exchange between the blown air and a heat medium;

an air outlet mode switching device that switches between a plurality of air outlet modes by switching proportions of air flow blown out from a plurality of outlets which includes a face air outlet that blows out the blown air to an upper body of an occupant and a foot air outlet that blows out the blown air to a lower body of an occupant, and

a control device that determines the availability factor of the blower and the air outlet mode, wherein

the control device:

limits the availability factor of the blower based on a temperature of the heat medium when the air outlet mode is a bi-level mode in which the blown air is blown out from both of the face air outlet and the foot air outlet;

when the air outlet mode is a face mode in which the blown air is blown out from the face air outlet, reduces limitation on the availability factor of the blower compared to when in the bi-level mode; and

controls the air outlet mode so that, in accordance with increase of an amount of insolation, it becomes more unlikely that the air outlet mode is determined to be the bi-level mode, and it becomes more likely that the air outlet mode is determined to be the face mode.

7. The air conditioner for the vehicle according to claim **6**, wherein the control device:

determines the availability factor of the blower based on an air-conditioning load; and

in accordance with increase of the amount of the insolation, narrows down a range of the air-conditioning load in which the air outlet mode is determined to be the bi-level mode is narrowed, and widens a range of the air-conditioning load in which the air outlet mode is determined to be the face mode.

* * * * *