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(19) **United States**(12) **Patent Application Publication**
Sawada et al.(10) **Pub. No.: US 2012/0222441 A1**(43) **Pub. Date: Sep. 6, 2012**(54) **HEAT CYCLE SYSTEM FOR MOBILE
OBJECT**(52) **U.S. Cl. 62/238.1**(57) **ABSTRACT**(75) **Inventors:** **Itsuro Sawada**, Hitachinaka-shi
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A heat cycle system for a mobile object includes: a refrigeration cycle system 10 in which a refrigerant flows; a first heat transfer system 20 in which a heat medium that controls a temperature of a heat-generating body 2 flows; a second heat transfer system 30 in which a heat medium that controls a state of air in an interior of the mobile object flows; a first intermediate heat exchanger 40 which is provided between the refrigeration cycle system 10 and the first heat transfer system 20 and in which the refrigerant and the heat medium exchange heat therebetween; a second intermediate heat exchanger 50 which is provided between the refrigeration cycle system 10 and the second heat transfer system 30 and in which the refrigerant and the heat medium exchange heat therebetween; a first interior heat exchanger 23 which is provided in the first heat transfer system 20 and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; a second interior heat exchanger 32 which is provided in the second heat transfer system 30 and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and a reservoir tank 24 that controls pressures in flow channels in which the heat media in the first and second heat transfer systems 20 and 30, respectively, flow; wherein the reservoir tank 24 is provided in common for the first and second heat transfer systems 20 and 30.

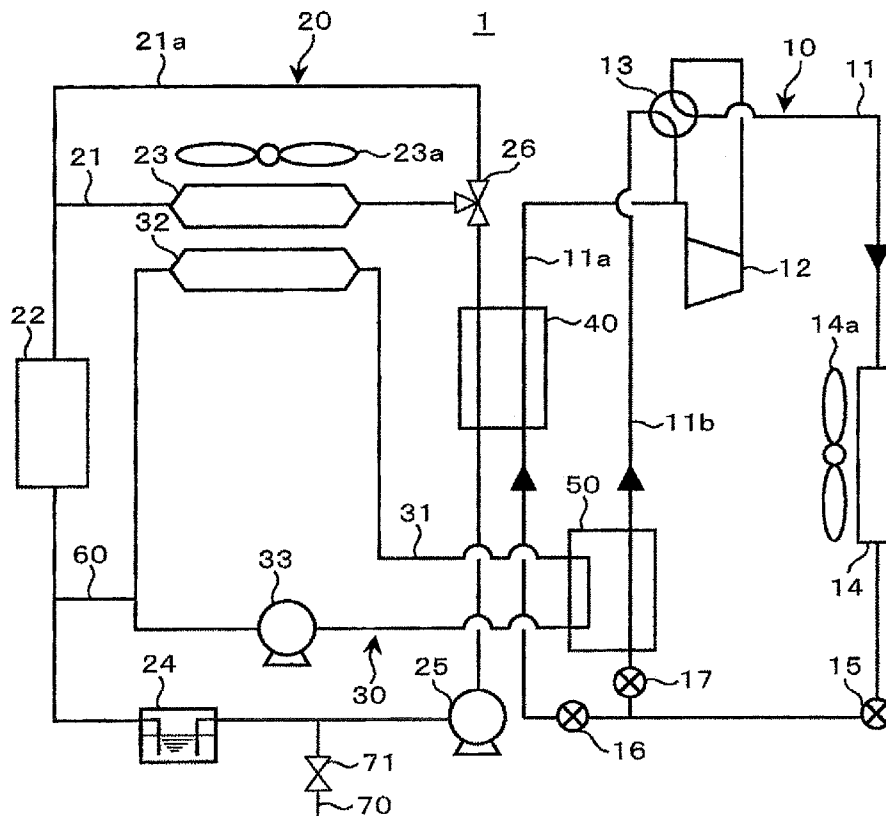
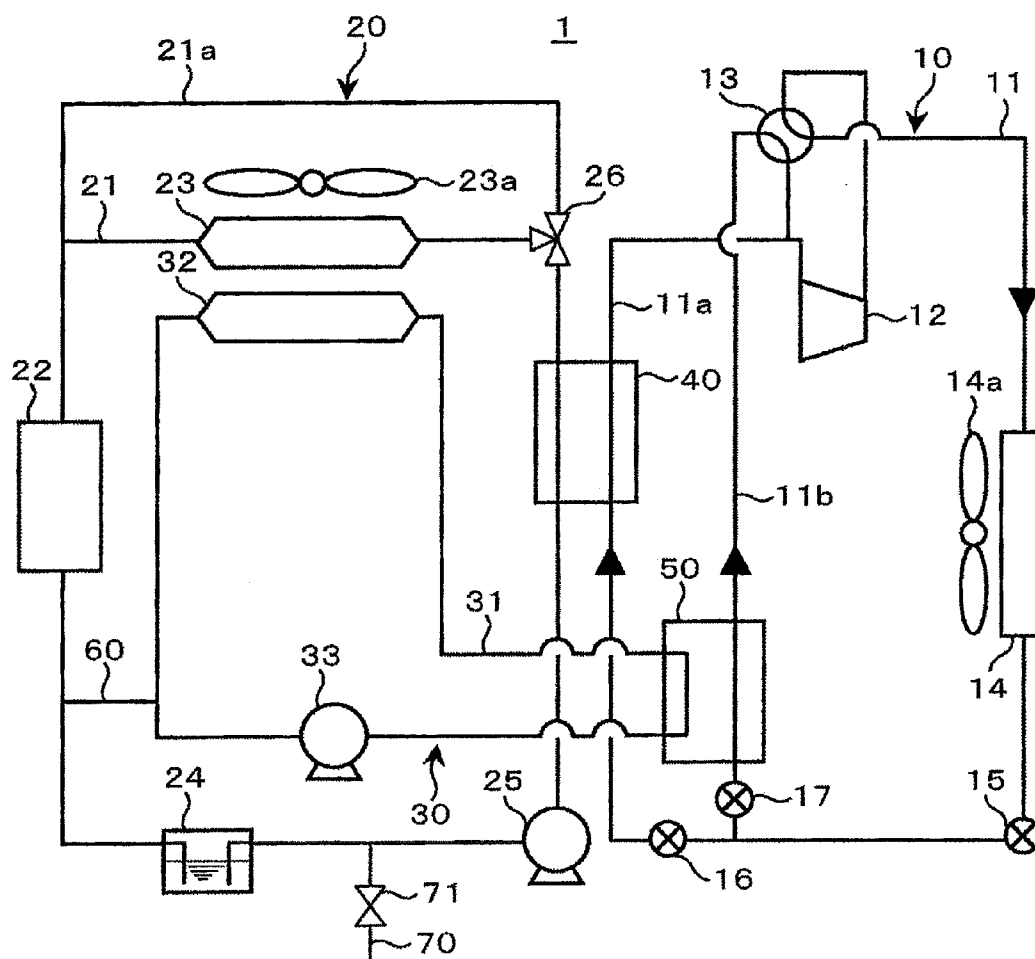


FIG.1



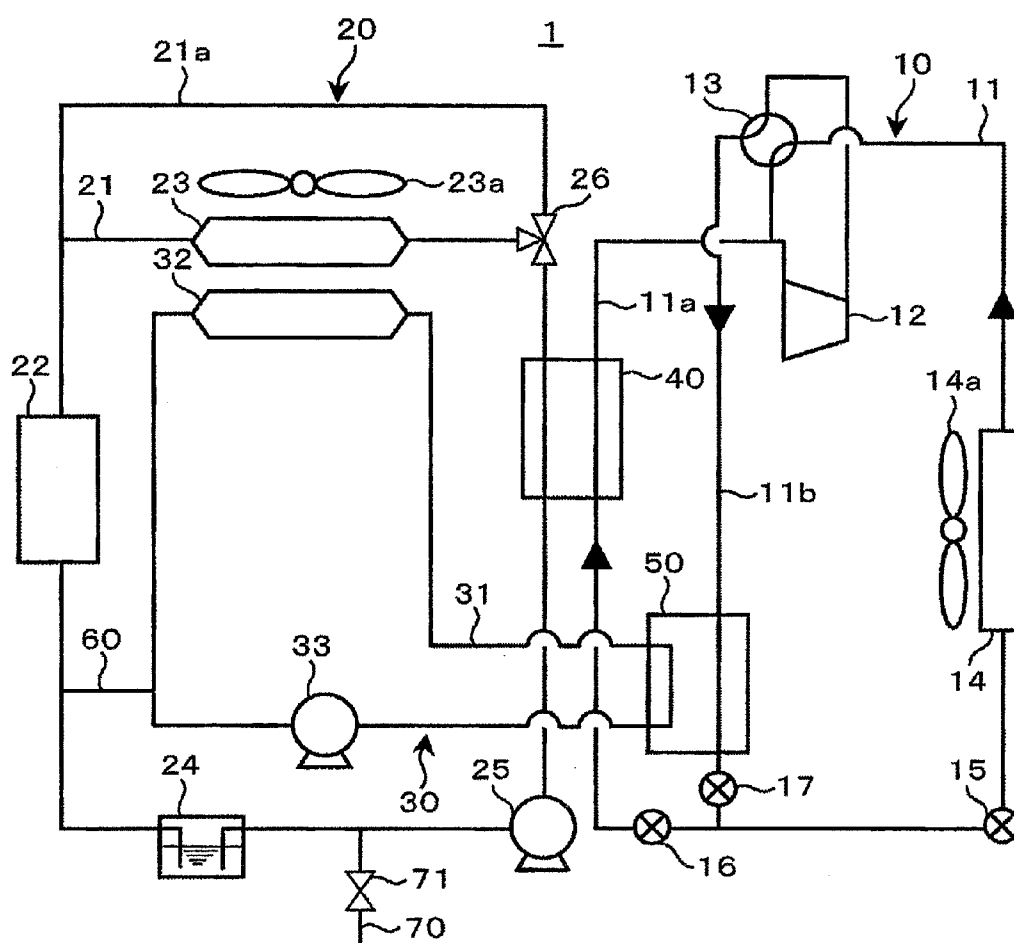
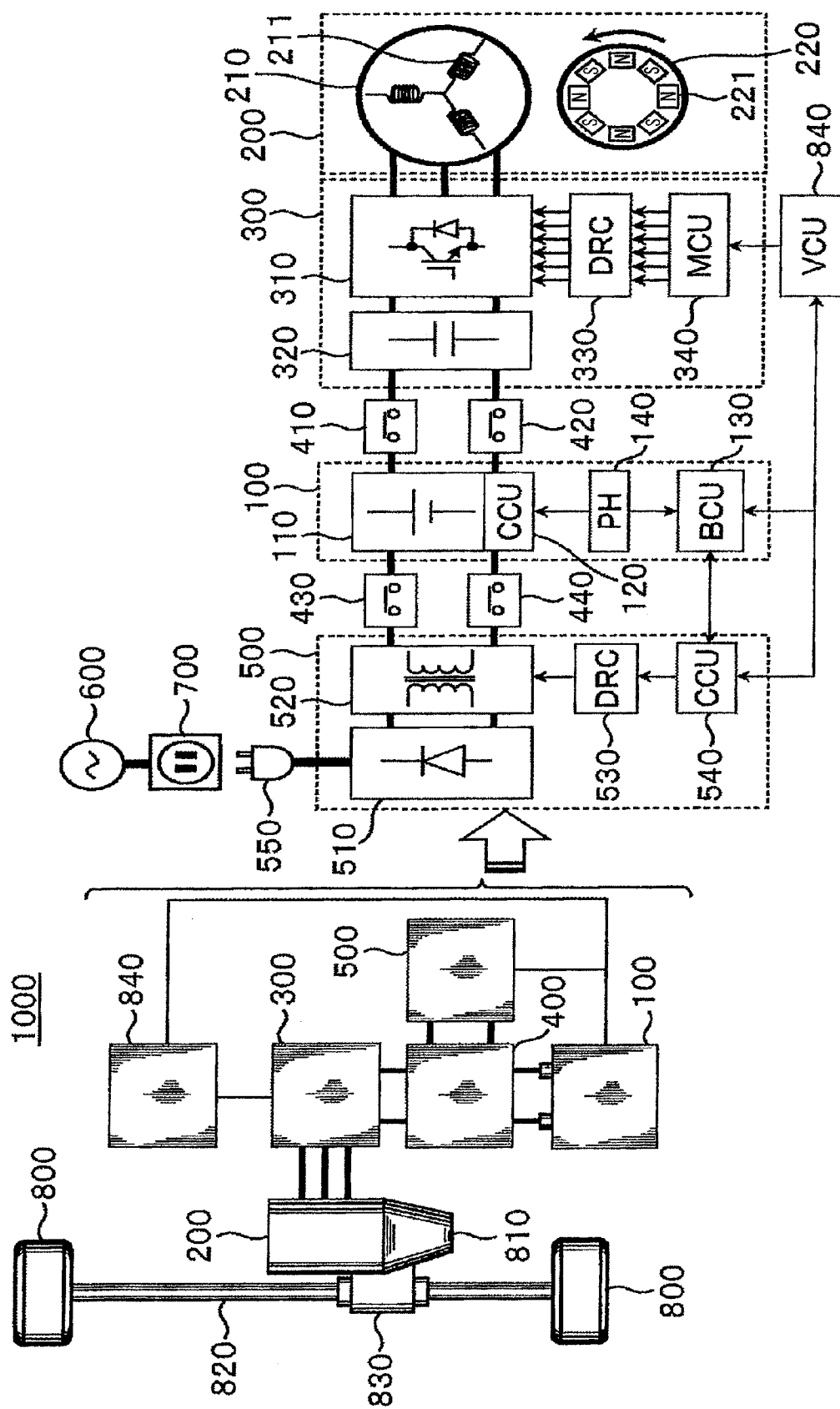


FIG. 3



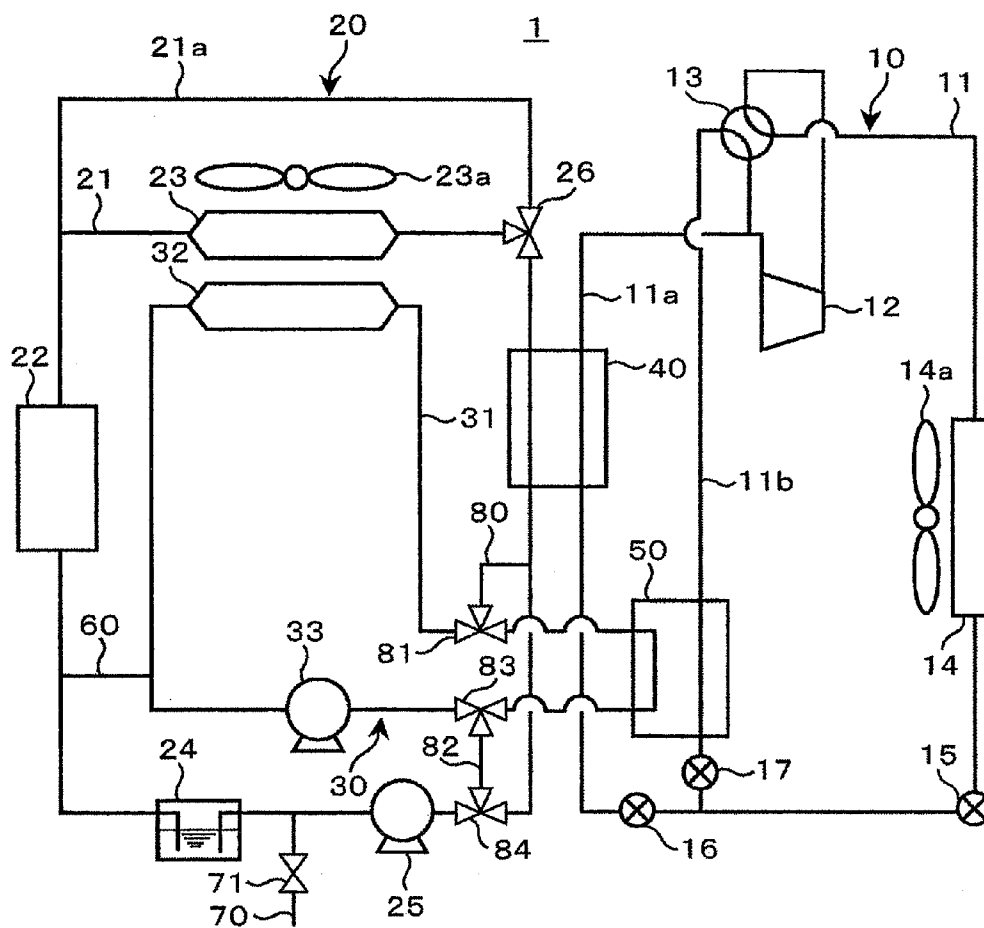


FIG.5

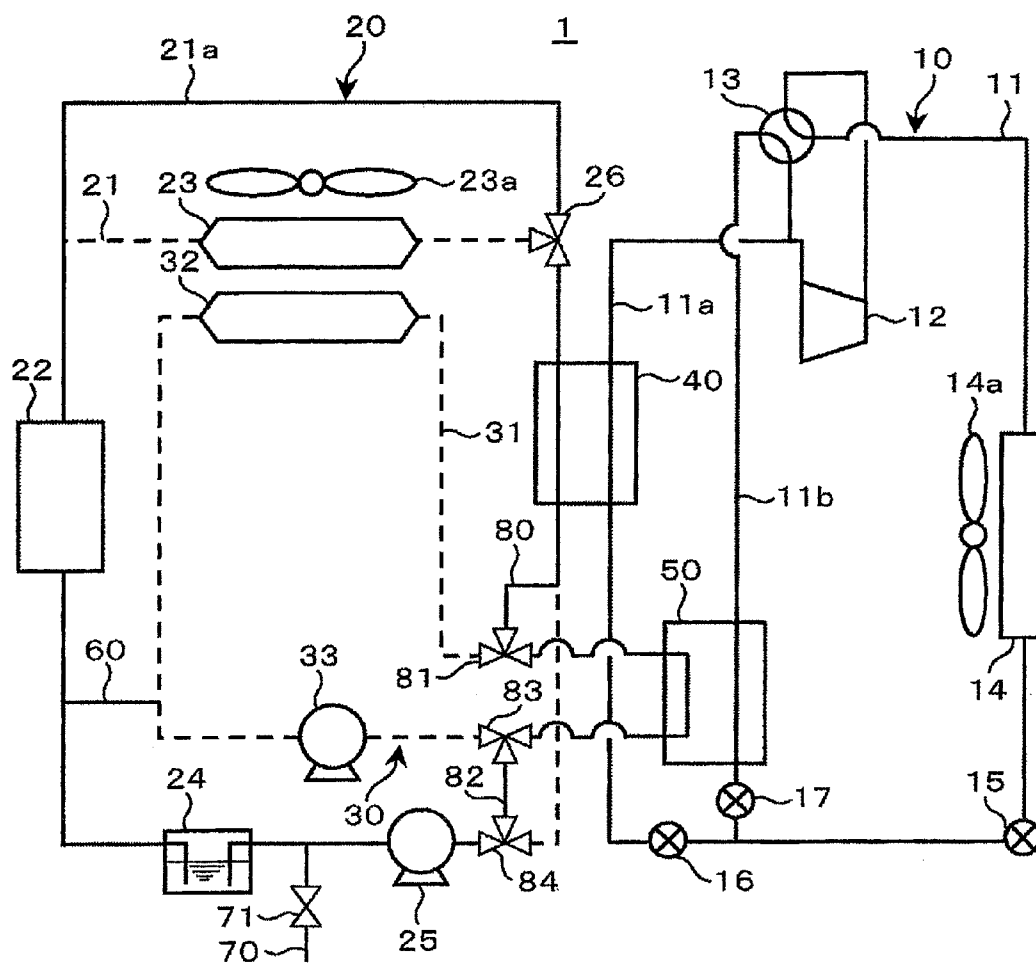


FIG.6

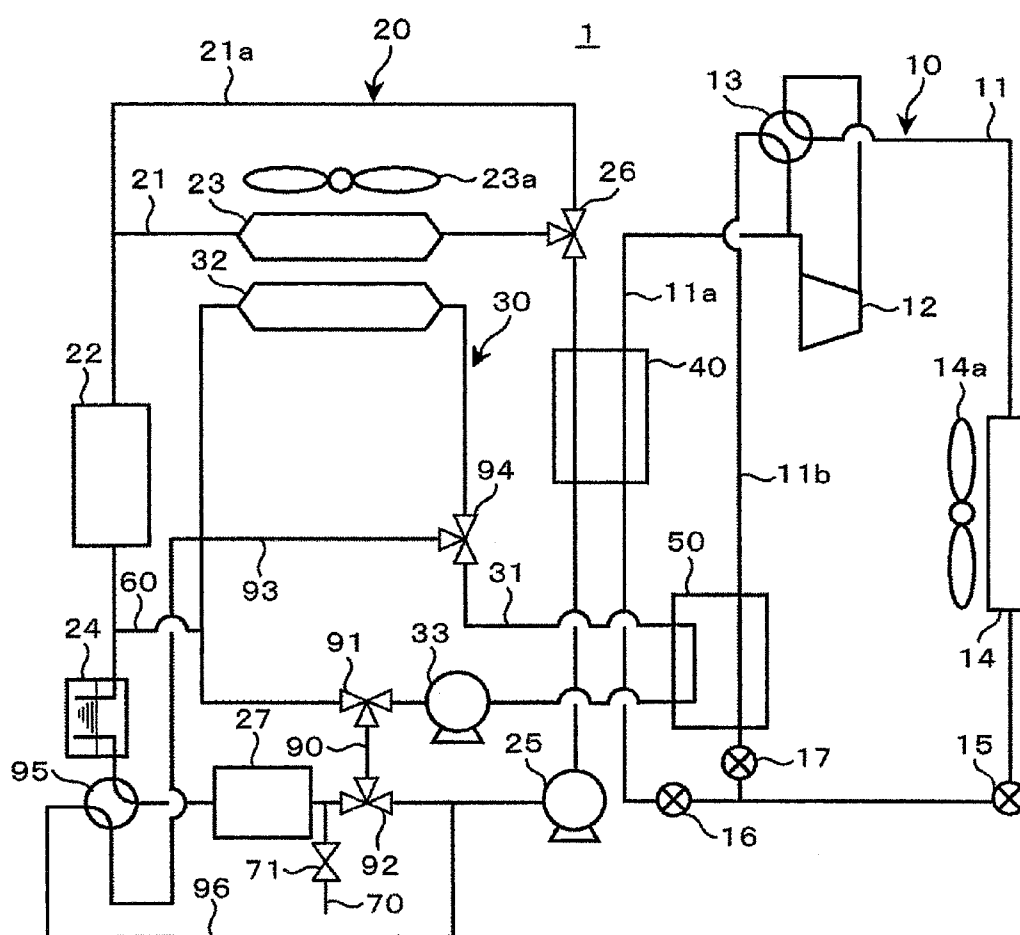


FIG. 7

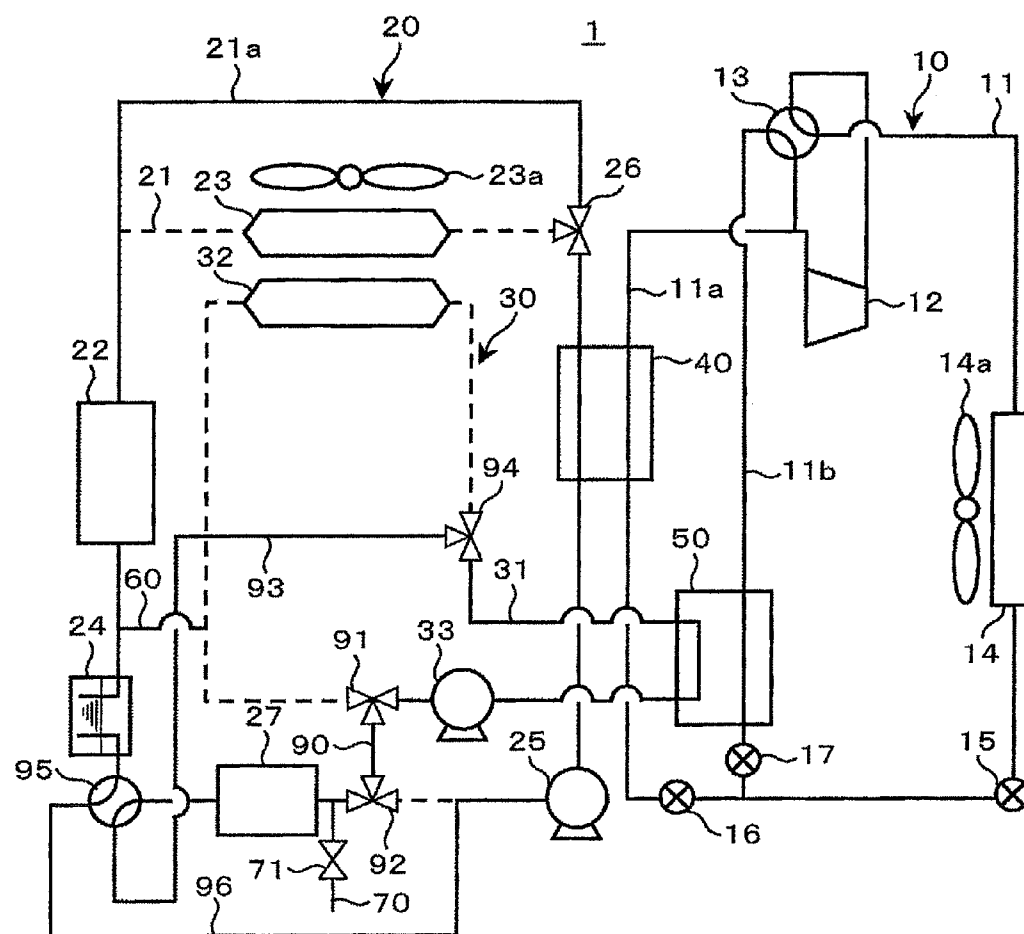
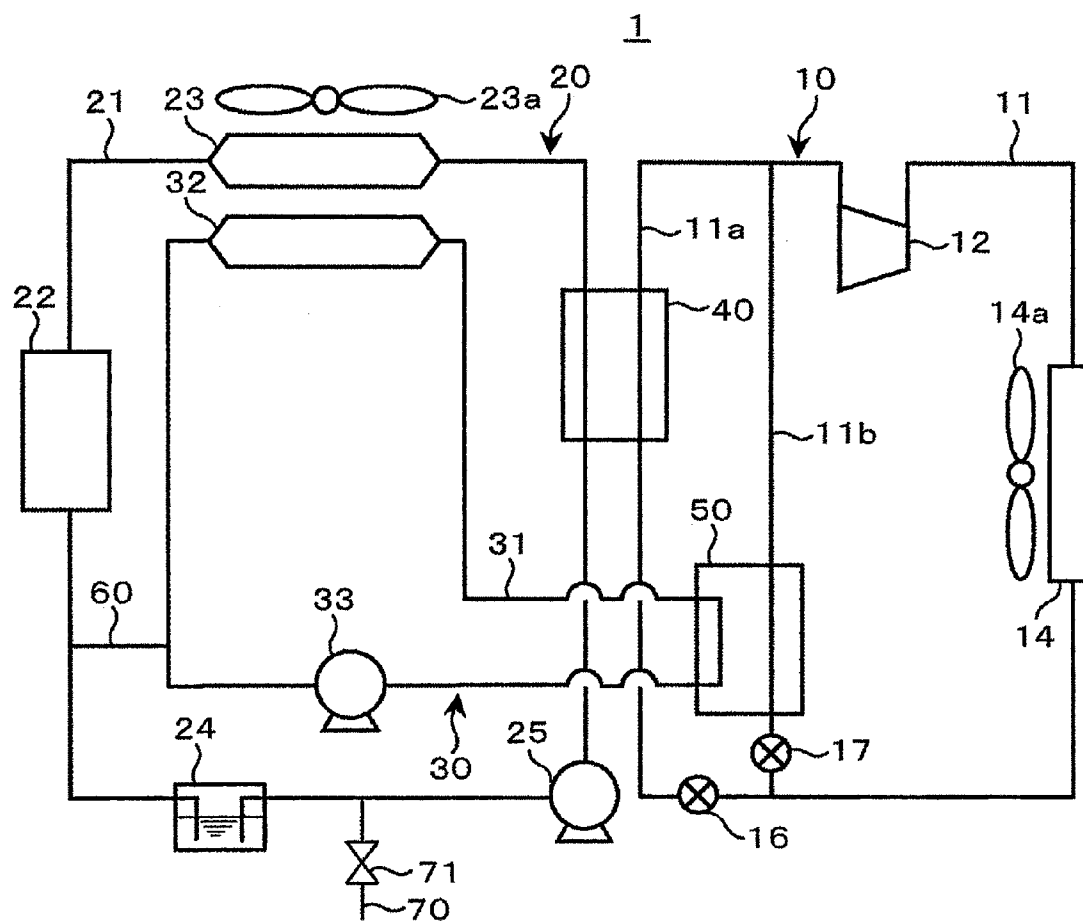


FIG.8



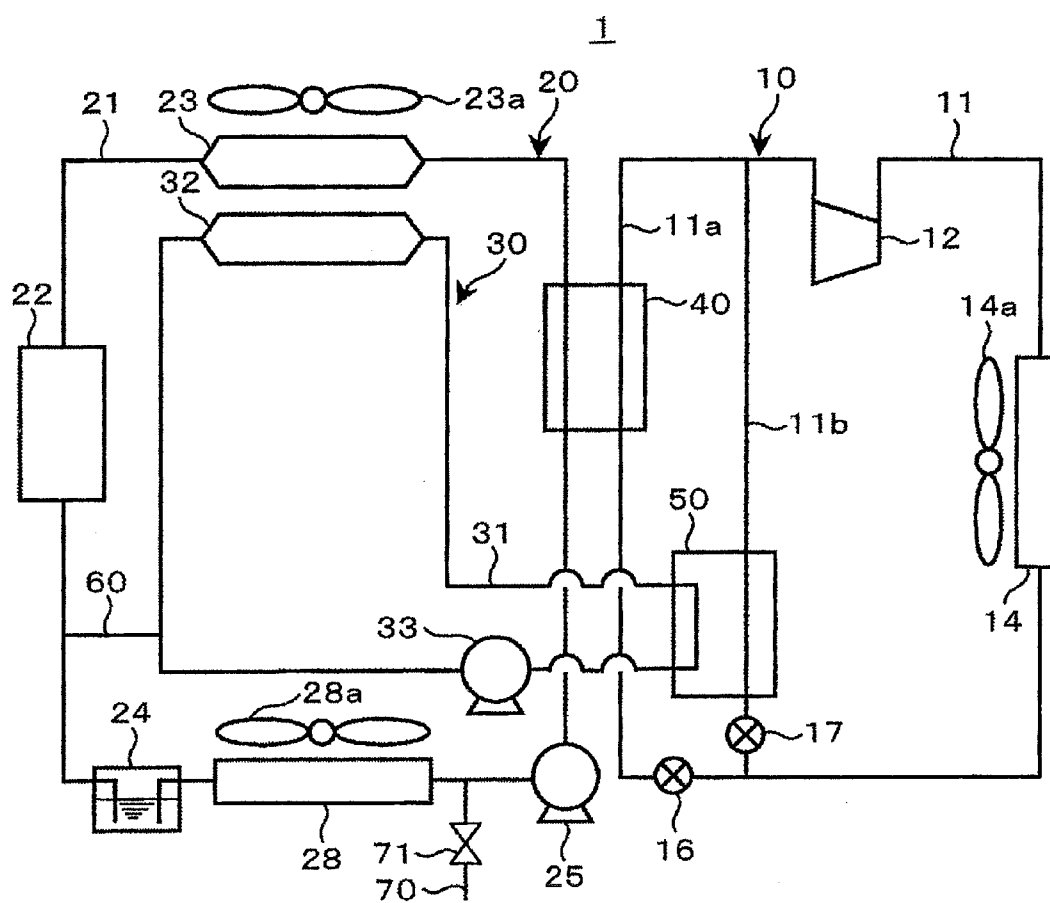
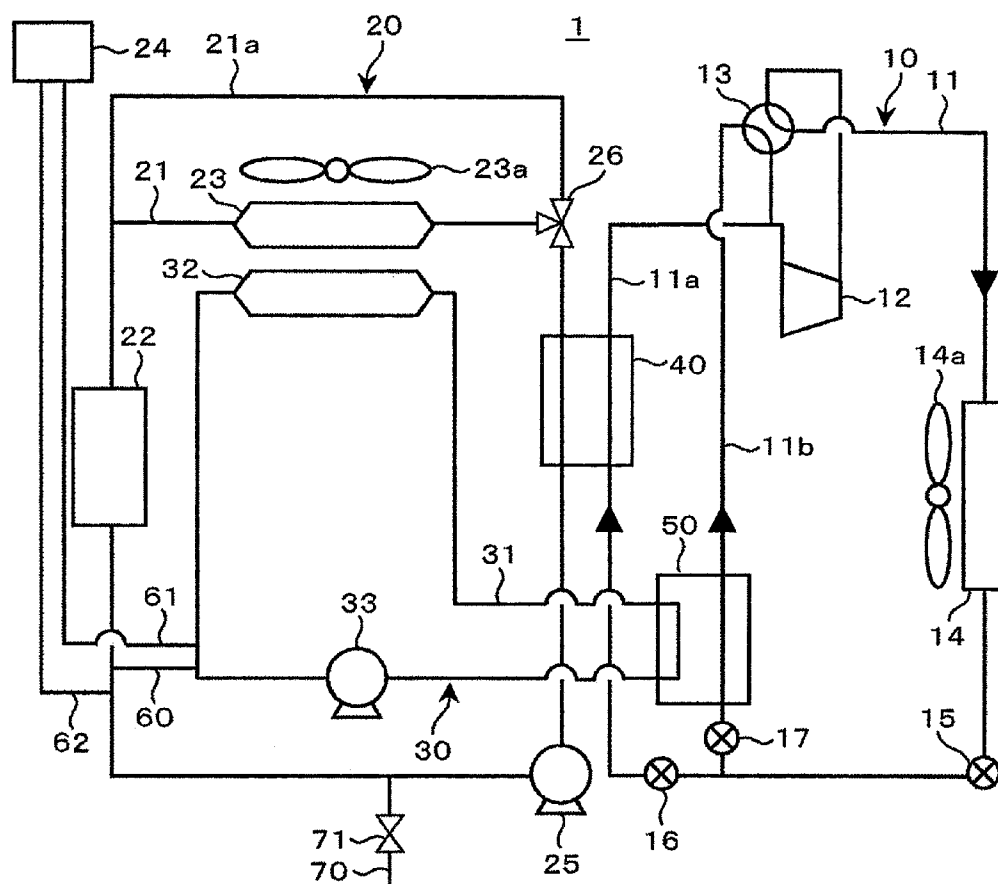


FIG.10



HEAT CYCLE SYSTEM FOR MOBILE OBJECT

TECHNICAL FIELD

[0001] The present invention relates to a heat cycle system installed in a mobile object.

BACKGROUND ART

[0002] A heat cycle system for a mobile object installed in the mobile object is known, which includes in an integrated manner a cooling system that cools heat-generating bodies such as battery cells and a DC/DC converter and an air-conditioning system that controls the state of air in the vehicle interior (see Patent Literature 1). This heat cycle system for a mobile object is configured such that air-conditioning of the vehicle interior and cooling of the heat-generating bodies are performed by thermally connecting a heat medium circulation cycle in which a heat medium supplied to an air-conditioning heat exchanger and the heat-generating bodies and a refrigeration cycle through a heat exchanger, thus enabling heat exchange between a refrigerant in the refrigeration cycle and the heat medium.

CITATION LIST

Patent Literature

[0003] [Patent Literature 1] Japanese Patent Application Laid-open Publication No. 2005-273998

SUMMARY OF INVENTION

Technical Problem

[0004] When installing in a mobile object a heat cycle system that includes in an integrated manner a cooling system and an air-conditioning system, it is possible that piping that constitutes flow channels and constituent components are arranged in a complicated manner in a narrow space. Taking into consideration maintainability and necessity of size reduction and cost reduction of the heat cycle system, it is desirable to simplify the system construction by size reduction or elimination of the constituent components or by sharing them.

[0005] In case that a further reduction in size and a further increase in power output in the mobile object having installed therein a heat cycle system, it is necessary to further increase the performance of cooling the heat-generating bodies. In this case, it may be conceivable to further increase the performance of cooling the heat-generating bodies by using additional heat exchangers or by further increasing the capacity of the heat exchanger. However, in view of the necessity of size reduction and cost reduction of the heat cycle system, it is desirable to increase the performance of cooling without using additional heat exchangers or without increasing the capacity of the heat exchanger.

Solution to Problem

[0006] According to a typical aspect, the present invention provides a heat cycle system for a mobile object whose system configuration can be simplified.

[0007] A heat cycle system for a mobile object according to a first aspect of the present invention, comprises: a refrigeration cycle system in which a refrigerant flows; a first heat transfer system in which a heat medium that controls a temperature of a heat-generating body flows; a second heat trans-

fer system in which a heat medium that controls a state of air in an interior of the mobile object flows; a first intermediate heat exchanger which is provided between the refrigeration cycle system and the first heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween; a second intermediate heat exchanger which is provided between the refrigeration cycle system and the second heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween; a first interior heat exchanger which is provided in the first heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; a second interior heat exchanger which is provided in the second heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and a reservoir tank that controls pressures in flow channels in which the heat media in the first and second heat transfer systems, respectively, flow; wherein the reservoir tank is provided in common for the first and second heat transfer systems.

[0008] According to a second aspect of the present invention, in the heat cycle system for a mobile object according to the first aspect, it is preferable that the reservoir tank is connected with a heat medium flow channel for the first heat transfer system and a heat medium flow channel for the second heat transfer system, respectively.

[0009] According to a third aspect of the present invention, in the heat cycle system for a mobile object according to the first aspect, it is preferable that the reservoir tank is provided in either one of the heat medium flow channel for the first heat transfer system or the heat medium flow channel for the second heat transfer system, and the heat medium flow channel for the first heat transfer system and the heat medium flow channel for the second heat transfer system communicate through a communication path.

[0010] According to a fourth aspect of the present invention, in the heat cycle system for a mobile object according to any one of the first to third aspects, it is preferable to further comprise: a drainage mechanism that discharges the heat media from the heat medium flow channel for the first heat transfer system and the heat medium flow channel for the second heat transfer system, wherein the drainage mechanism is provided in common between the first heat transfer system and the second heat transfer system.

[0011] According to a fifth aspect of the present invention, in the heat cycle system for a mobile object according to any one of the first to fourth aspects, it is preferable to further comprises an exterior heat exchanger, provided in the first heat transfer system, that exchanges heat between the heat medium and exterior air.

[0012] A heat cycle system for a mobile object according to a sixth aspect of the present invention, comprises: a refrigeration cycle system in which a refrigerant flows; a first heat transfer system in which a heat medium that controls a temperature of a heat-generating body flows; a second heat transfer system in which a heat medium that controls a state of air in an interior of the mobile object flows; a first intermediate heat exchanger which is provided between the refrigeration cycle system and the first heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween; a second intermediate heat exchanger which is provided between the refrigeration cycle system and the second heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween; a first interior heat

exchanger which is provided in the first heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; a second interior heat exchanger which is provided in the second heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and a flow channel connection control unit that controls connection of a flow channel of the first heat transfer system and a flow channel of the second heat transfer system such that a heat medium fed to the heat-generating body is flown through the first and second intermediate heat exchangers in series.

[0013] According to a seventh aspect of the present invention, in the heat cycle system for a mobile object according to the sixth aspect, it is preferable that when a state is reached where an amount of heat exchange between the heat medium fed to the heat-generating body and the refrigerant is to be made larger than an amount of heat exchange between a heat medium fed to the heat-generating body and the refrigerant at the first intermediate heat exchanger, the flow channel connection control unit controls the connection between the flow channels such that a heat medium fed to the heat-generating body flows through the first and second intermediate heat exchangers in series.

[0014] A heat cycle system for a mobile object according to an eighth aspect of the present invention, comprises: a refrigeration cycle system in which a refrigerant flows; a first heat transfer system in which a heat medium that controls temperatures of at least two heat-generating bodies flows; a second heat transfer system in which a heat medium that controls a state of air in an interior of the mobile object flows; a first intermediate heat exchanger which is provided between the refrigeration cycle system and the first heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween; a second intermediate heat exchanger which is provided between the refrigeration cycle system and the second heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween; a first interior heat exchanger which is provided in the first heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; a second interior heat exchanger which is provided in the second heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and a flow channels switch unit that switches connections between the at least two heat-generating bodies and flow channels of the first and second heat transfer systems such that assuming the at least two heat-generating bodies are divided into two heat control object groups, the heat medium that flows in the first heat transfer system is circulated to one of the two heat control object groups and the heat medium that flows in the second heat transfer system is circulated to the other of the two heat control object groups.

[0015] According to a ninth aspect of the present invention, in the heat cycle system for a mobile object according to the eighth aspect, it is preferable that when a state is reached where an amount of heat exchange between the heat medium fed to the at least two heat-generating bodies and the at least two heat-generating bodies is to be made larger than an amount of heat exchange between the at least two heat-generating bodies and the heat medium of the first heat transfer system, the flow channels connection control unit controls the connections between the flow channels such that the heat

medium that flows in the first heat transfer system is circulated to one of the temperature control object groups while the heat medium that flows in the second heat transfer system is circulated to the other of the temperature control object groups.

[0016] According to a tenth aspect of the present invention, in the heat cycle system for a mobile object according to any one of the sixth to ninth aspects, it is preferable to further comprise: a reservoir tank that controls respective pressures in flow channels in which the heat media of the first and second heat transfer systems flow, wherein the reservoir tank is provided in common to the first and second heat transfer systems.

[0017] According to an eleventh aspect of the present invention, in the heat cycle system for a mobile object according to any one of the sixth to tenth aspects, it is preferable to further comprise: a drainage mechanism that discharges the heat medium from the heat medium flow channel for the first heat transfer system and the heat medium flow channel for the second heat transfer system, wherein the drainage mechanism is provided in common between the first heat transfer system and the second heat transfer system.

[0018] According to a twelfth aspect of the present invention, in the heat cycle system for a mobile object according to any one of the sixth to eleventh aspects, it is preferable to further comprise an exterior heat exchanger, provided in the first heat transfer system, that exchanges heat between the heat medium and exterior air.

ADVANTAGEOUS EFFECT OF THE INVENTION

[0019] According to the present invention, the maintainability of the heat cycle system for a mobile object can be improved and the heat cycle system for a mobile object can be down-sized at reduced cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 shows a piping system diagram of a construction of a heat cycle system for an electric vehicle according to a first embodiment of the present invention, indicating a refrigerant circulating state in which air-conditioning of the vehicle interior is in an air-cooling mode and temperature control of a heat-generating body is in a cooling mode;

[0021] FIG. 2 shows a piping system diagram of the heat cycle system shown in FIG. 1, indicating a refrigerant circulating state in which air-conditioning of the vehicle interior is in an air-heating mode and temperature control of a heat-generating body is in a cooling mode;

[0022] FIG. 3 shows a configuration diagram of a construction of an electric drive system of the electric vehicle having installed therein the heat cycle system shown in FIG. 1;

[0023] FIG. 4 shows a piping system diagram of a construction of a heat cycle system for an electric vehicle according to a second embodiment of the present invention;

[0024] FIG. 5 shows a piping system diagram of the heat cycle system shown in FIG. 4, showing a circulation channel with two heat medium circulation paths connected in series;

[0025] FIG. 6 shows a piping system diagram of a construction of a heat cycle system for an electric vehicle according to a third embodiment of the present invention;

[0026] FIG. 7 shows a piping system diagram of the heat cycle system shown in FIG. 6, showing a circulation circuit when one of the heat-generating bodies is cooled with a heat medium that flows through one of the heat medium circula-

tion paths and the other of the heat-generating bodies is cooled with a heat medium that flows through the other of the heat medium circulation paths;

[0027] FIG. 8 shows a piping system diagram of a construction of a heat cycle system for an electric vehicle according to a fourth embodiment of the present invention;

[0028] FIG. 9 shows a piping system diagram of a construction of a heat cycle system for an electric vehicle according to a fifth embodiment of the present invention; and

[0029] FIG. 10 shows a piping system diagram of a construction of a heat cycle system for an electric vehicle according to a sixth embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0030] According to the embodiments described below, explanation is made taking an example of a case where the present invention is applied to a heat cycle system of a genuine electric vehicle that uses an electric motor as a sole drive power source for the vehicle.

[0031] The configurations of the embodiments explained below may be applied as a vehicular air-conditioning systems for electric vehicles that employs as drive power sources both an engine, that is an internal combustion engine, and an electric motor s, for example, hybrid vehicles (passenger cars), hybrid trucks, hybrid buses and so on.

[0032] First, referring to FIG. 3, explanation is made on an electric-motor driving system for a pure electric vehicle (hereafter, simply referred to as "EV") to which the heat cycle system according to the present invention is applied.

[0033] FIG. 3 shows a configuration of the drive system EV1000 and electrical connection of each component in an electric-motor drive system that constitutes a part thereof.

[0034] Note that in FIG. 3, thick solid lines indicate high voltage lines and thin solid lines indicate low voltage lines.

[0035] An axle 820 is rotatably supported in the front portion or the rear portion of the vehicle body (not shown). On both ends of the axle 820 is provided a pair of driving wheels 800. Though not shown, at the front portion or the rear portion of the vehicle body is rotatably supported an axle provided with a pair of non-driving wheels on both ends thereof. EV 1000 shown in FIG. 3 is of a front wheel drive type having the driving wheels 800 as front wheels and the non-driving wheels as rear wheels. However, a rear wheel drive type having the driving wheels 800 as rear wheels and the non-driving wheels as front wheels may also be employed.

[0036] In the midportion of the axle 820 is provided a differential gear (hereafter, referred to as "DIF") 830. The axle 820 is mechanically connected to the output side of the DIF 830. To the input side of DIF 830 is mechanically connected an output shaft of a transmission 810. DIF 830 is a differential power distribution mechanism that distributes rotative drive force transmitted via the transmission 810 with speed change to the left and right axles 820. To the input side of the transmission 810 is mechanically connected the output side of a motor generator 200.

[0037] The motor generator 200 is a rotating electrical machine that includes an armature (corresponding to the stator in EV 1000 shown in FIG. 3) 210 provided with armature winding 211 and a field system provided with a permanent magnet 221 (corresponding to the rotor in EV 1000 shown in FIG. 3) and arranged opposite to the armature 210 via a gap. The motor generator 200 functions as a motor when EV 1000 is on power driving and as a generator when it is regenerating.

[0038] When the motor generator 200 functions as a motor, electric energy accumulated in a battery 100 is supplied to the winding of the armature 211 through an inverter 300. As a result, the motor generator 200 generates rotative power (mechanical energy) due to magnetic interaction between the armature 210 and the field system 220. The rotative power output from the motor generator 200 is transmitted to the axle 820 via the transmission 810 and DIF 830 to drive the driving wheels 800.

[0039] When the motor generator 200 functions as a generator, the mechanical energy (rotative force) transmitted from the driving wheels 800 is transmitted to the motor generator 200 to drive the motor generator 200. In this manner, when the motor generator 200 is driven, the magnetic fluxes of the field system 220 interlink with the winding 211 of the armature to induce voltage. Due to this, the motor generator generates power. The power output from the motor generator 200 is supplied to the battery 100 through the inverter 300. As a result, the battery 100 is charged.

[0040] The motor generator 200, particularly the temperature of the armature 210 is controlled by the heat cycle system explained later such that the temperature falls within an allowable temperature range. The armature is a heat generating component, so that it is necessary to cool it. When ambient temperature is relatively low, it may sometimes be necessary to warm it in order to obtain specified electric properties.

[0041] The motor generator 200 is driven by controlling electric power by the inverter 300 between the armature 210 and the battery 100. That is, the inverter 300 is a control device for the motor generator 200. The inverter 300 is a power converting device that converts the power from direct current to alternating current or from alternating current to direct current by switching actions of a switching semiconductor element. The inverter 300 includes a power module 310, a drive circuit 330, an electrolytic capacitor 320, and a motor controller 340. The drive circuit 330 drives a switching semiconductor device implemented in the power module 310. The electrolytic capacitor 320 is electrically connected with the direct current side of the power module 310 in parallel to smooth the direct current voltage. The motor controller 340 generates a switching command for switching semiconductor device of the power module 310, and outputs a signal corresponding to the switching command to the drive circuit 330.

[0042] The power module 310 includes three series circuits (each series circuit is an arm for one phase) for three phases, wherein each of series circuit (arm for one phase) has two switching semiconductor devices (one for an upper arm and the other for a lower arm) electrically connected in series. The power module 310 comprises six switching semiconductor devices which are implemented on a substrate and are electrically connected with a connection conductor such as an aluminum wire, so that three series circuits corresponding to three phases are electrically connected in parallel (three-phase bridge connection) to constitute a power conversion circuit.

[0043] As the switching semiconductor device, use is made of a metal oxide film semiconductor field effect transistor (MOSFET) or an insulated gate type bipolar transistor (IGBT). Here, in case where the power conversion circuit is constructed by MOSFET, a parasitic diode is present between a drain electrode and a source electrode, so that it is unnecessary to separately provide a diode device therebetween. On the other hand, in case where the power conversion circuit is constructed by IGBT, no diode element exists between a

collector electrode and an emitter electrode, so that it is necessary to electrically connect a diode device with reversed direction in parallel between the collector electrode and the emitter electrode.

[0044] One side of each upper arm, which is the side opposite to a side that is connected to a lower arm (collector electrode side in the case of IGBT) is extending to outside from a direct current side of the power module **310** and is connected to a positive electrode side of the battery **100**. The other side of each lower arm, which is the side opposite to a side that is connected with a corresponding upper arm (emitter electrode side in the case of IGBT) is extending to outside from a direct current side of the power module **310** and is connected to a negative electrode side of the battery **100**. A midpoint of each pair of upper and lower arms, i.e., a connection point, at which a side of the upper arm connected with the lower arm (emitter electrode side of the upper arm in the case of IGBT) and a side of the lower arm connected with the upper arm are joined, is extending to outside from an alternate current side of the power module **310** and electrically connected to a wiring of the armature **211** of a corresponding phase.

[0045] The electrolytic capacitor **320** is provided in order to suppress voltage fluctuation that is caused by high speed switching of the switching semiconductor devices and parasite inductance in the power conversion circuit. The electrolytic capacitor **320** functions as a smoothing capacitor that removes an alternate current component contained in a direct current component. The smoothing capacitor may be a film capacitor.

[0046] The motor controller **340** is an electronic circuit device that generates switch command signals (for example, PWM (pulse width modulation) signals) for six switching semiconductor devices corresponding to a torque command signal output from a vehicle controller **840** that controls the vehicle in whole and outputs the generated switch command signals to the drive circuit **330**.

[0047] The drive circuit **330** is an electronic circuit device that generates drive signals for six semiconductor devices corresponding to a switch command signal output from the motor controller **340** and outputs the generated drive signals to gate electrodes of the six switching semiconductor devices.

[0048] In the inverter **300**, in particular in the power module **310** and in the electrolytic capacitor **320**, their temperatures are controlled by the heat cycle system described later so that the temperatures fall within an allowable temperature range. Since the power module **310** and the electrolytic capacitor **320** are heat-generating components, so that it is necessary to cool them. In case when the ambient temperature is relatively low, it may be necessary to warm them in order to obtain specified functioning and electrical properties.

[0049] The vehicle controller generates a motor torque command signal for the motor controller **340** based on a plurality of state parameters that indicates the vehicle operational state and outputs the generated motor torque command signal to the motor controller **340**. Examples of the plurality of state parameters that indicates the vehicle operational state include a torque demand (depression amount of the accelerator pedal or a throttle position) and vehicle speed, and so on.

[0050] The battery **100** is a battery that generates a high voltage of 200 volts or higher as nominal output voltage, which constitutes a drive power source for the motor generator **200**. The battery **100** is electrically connected with the

inverter **300** and a charger **500** through a junction box **400**. A lithium ion battery is used as the battery **100**.

[0051] Other electrical storage devices such as a lead battery cell, a nickel hydride battery cell, an electrical double layer capacitor, and a hybrid capacitor may be used as the battery **100**.

[0052] The battery **100** is an electrical storage device that is charged and discharged by the inverter **300** and the charger **500**. It includes the battery cell unit **110** and a control unit as major parts.

[0053] The battery cell unit **110** functions as a storage device of electrical energy and is constructed by a plurality of lithium ion battery cells that can store and discharge electrical energy (charge and discharge of direct current power) electrically connected in series. The battery cell unit **110** is electrically connected with the inverter **300** and the charger **500**.

[0054] The control unit is an electronic control device constructed by a plurality of electronic circuit components. It manages and controls the state of the battery cell unit **110** and provides information about allowable charge and discharge amount to the inverter **300** and the charger **500** to control input and output of electrical energy in and from the battery cell unit **110**.

[0055] The electronic control device is constructed by two hierarchical levels from the viewpoint of function. It includes the battery controller **130** that corresponds to a higher level (parent) in the battery **100** and the cell controller **120** that corresponds to a lower level (child) with respect to the battery controller **130**.

[0056] The cell controller **120** operates as a subordinate to the battery controller **130** based on a command signal output from the battery controller **130**. It includes a plurality of battery cell management means that manages and controls respective states of the plurality of the lithium ion battery cells. The plurality of battery management means is constructed by integrated circuits (ICs), respectively. In case where the battery cell unit **110** has a structure such that a plurality of lithium ion battery cells electrically connected in series is divided into a plurality of groups, the plurality of integrated circuits is provided corresponding to the plurality of groups, respectively. Each integrated circuit detects respective voltages and overcharge-overdischarge abnormalities of the plurality of lithium ion battery cells contained in the corresponding group.

[0057] The battery controller **130** is an electronic control device that manages and controls the state of the battery cell unit **110** and notifies an allowable charge and discharge amount to the vehicle controller **840** or the motor controller **340** to control input and output of electric energy in and from the battery cell unit **110**; the battery controller **130** is provided with a state detection means. The state detection means is a calculation processor such as a microcomputer or a digital signal processor.

[0058] A plurality of signals is input to the state detection means of the battery controller **130**. The plurality of signals includes a measurement signal output for a current measurement means for measuring charge and discharge current of the battery cell unit **110**, a measurement signal output from a voltage measurement means for measuring charge and discharging voltage of the battery cell unit **110**, a measurement signal output from a temperature measurement means for measuring temperatures of the battery cell unit **110** and of some of the lithium ion battery cells, respectively, a detection signal relating to terminal voltage of the plurality of lithium

ion battery cells output from the cell controller **120**, an abnormality signal output from the cell controller **120**, an on-off signal based on an action of an ignition key switch, and a signal output from the vehicle controller **840** or the motor controller **340**, which is a control device of a higher hierarchical level than the battery controller **130**.

[0059] The state detection means of the battery controller **130** performs a plurality of calculations based on a plurality of informations. The plurality of informations includes information obtained from the above-mentioned input information, preset characteristics information of the lithium ion battery and calculation information necessary for calculations. The plurality of calculations includes calculations to detect SOC (state of charge) and SOH (state of health) of the battery cell unit **110**, calculations for balancing states of charge among the plurality of lithium ion battery cells, and calculations for controlling the charge and discharge amount of the battery cell unit **110**. The state detection means of the battery controller **130**, based on results of these calculations, generates and outputs a plurality of signals including a command signal to the cell controller **120**, a signal relating to allowable charge and discharge amount for controlling the charge and discharge amount of the battery cell unit **110**, a signal relating to SOC of the battery cell unit **110**, and a signal relating to SOH of the battery cell unit **110**.

[0060] The state detection means of the battery controller **130** generates and outputs a plurality of signals including a command signal to open the first positive and negative electrode relays **410**, **420**, and a signal for notifying abnormal state based on the abnormality signal output from the cell controller **120**.

[0061] The battery controller **130** and the cell controller **120** are constructed so as to communicate signals therebetween through a signal transmission path but are electrically insulated from each other. This is because they have different operation power sources and different base potentials from each other. To this end, an insulator **140** such as a photocoupler, a capacitive coupling element, or a transformer is provided on the signal transmission path between the battery controller **130** and the cell controller **120**. As a result, the battery controller **130** and the cell controller **120** can transmit signals having different base potentials to each other.

[0062] In the battery **100**, in particular, in the battery cell unit **110**, its temperature is controlled so that the temperature falls within the allowable temperature range by the heat cycle system described later. The battery cell unit **110** is a heat-generating component, and therefore it needs to be cooled and in case when the ambient temperature is relatively low, it may sometimes be necessary to be warmed up in order to obtain specified input and output characteristics.

[0063] The electric energy stored in the battery **100** is used as a drive power of the electric-motor driving system that drives EV **1000**. Accumulation of electric energy in the battery **100** is achieved by exploiting a regenerated power generated by a regeneration operation of the electric-motor driving system, a power taken from a commercial power source for domestic use, or a power purchased from a charging station.

[0064] In case the battery **100** is to be charged from a commercial power source **600** for domestic use, a power source plug **550** at the end of a power cable, which is electrically connected with an external power source connection terminal of the charger **500**, is inserted into an electric outlet **700** on the commercial power source **600** side to electrically

connect the charger **500** and the commercial power source **600** with each other. Alternatively, in case where the battery **100** is to be charged from a power feeder in the charging station, the power cable extending from the power feeder of the charging station is connected with an external power source connection terminal of the charger **500** to electrically connect the charger **500** and the power feeder of the charging station with each other. As a result, alternate current power is supplied from the commercial power source **600** or from the power feeder of the charging station to the charger **500**. The charger **500** converts the supplied alternate current power into direct current power and controls the voltage to a charging voltage of the battery **100** before supplying the power to the battery **100**. As a result, the battery **100** is charged.

[0065] Charging of the battery **100** from the power feeder of the charging station can be performed basically in the same manner as the charging of the battery **100** from the commercial power source **600** at home. However, the capacity of current supplied to the charger **500** and charging time are different between the charging from the commercial power source **600** at home and the charging from the power feeder of the charging station. The charging from the power feeder of the charging station can charge a larger capacity of current in a shorter charging time than the charging from the commercial power source **600** at home. That is, the charging from the power feeder of the charging station enables rapid charging.

[0066] The charger **500** is a power conversion unit that converts the alternate current power supplied from the commercial power source **600** at home or the alternate current power supplied from the power feeder of the charging station into direct current power and further boosts the converted direct current power to a charging voltage for supplying it to the battery **100**. The charger **500** includes as main components an alternate current-direct current conversion circuit **510**, a booster circuit **520**, a drive circuit **530**, and a charging controller **540**.

[0067] The alternate current-direct current conversion circuit **510** is a power conversion circuit that converts the alternate current power supplied from an external power source to direct current power and outputs the converted direct current power, and comprises a rectifier circuit and a power factor improvement circuit. The rectifier circuit is constructed by, for example, a plurality of diode devices in bridge connection structure and rectifies alternate current power supplied from an external power source into direct current power. The power factor improvement circuit is electrically connected to the direct current side of the rectifier circuit and improves the power factor of the rectifier circuit output. As the circuit that converts alternate current power into direct current power, a circuit may be constructed in bridge-connecting a plurality of switching semiconductor devices, to each of which is parallel connected with a diode element in reverse direction.

[0068] The booster circuit **520** is a power conversion circuit that boosts the direct current power output from the alternate current-direct current circuit **510** (power factor improvement circuit) up to the charging voltage of the battery **100** and is constructed by, for example, DC-DC converter of an insulated type. The DC-DC converter of an insulated type is constructed by a transformer, a conversion circuit, a rectifier circuit, a smoothing reactor, and a smoothing capacitor. The conversion circuit includes a plurality of switching semiconductor devices that are connected in bridge connection and are electrically connected to the primary wiring side of the transformer, converting the direct current power output from

the alternate current-direct current conversion circuit **510** into alternate current power and inputs the converted alternate current power into the primary wiring side of the transformer. The rectifier circuit is constructed by a plurality of diode elements connected in bridge connection. It is electrically connected to the secondary wiring side of the transformer and rectifies the alternate current power generated at the secondary wiring side of the transformer into direct current power. The smoothing reactor is electrically connected in series to the positive electrode side on the output side (direct current side) of the rectifier circuit. The smoothing capacitor is electrically connected with between the positive and negative electrodes on the output side (direct current side) of the rectifier circuit.

[0069] The charge controller **540** is an electronic circuit unit constructed by implementing a plurality of electronic components including an arithmetic processing unit such as a microcomputer packed on a circuit board. The charging controller **540** starts and stops charging of the battery **100** by the charger **500** and controls power, voltage, current and so on supplied from the charger **500** to the battery **100** upon the charging. To perform such controls, the charging controller **540** generates switch command signals (for example, PWM (pulse width-modulated modulation) signals) for a plurality of switching semiconductor devices of the boost circuit **520** in response to the signal output for the vehicle controller **840** and the signal output from the controller of the battery **100** and outputs the generated signals to the drive circuit **530**.

[0070] The vehicle controller **840** monitors, for example, the voltage of the input side of the charger **500**, and outputs a command signal to start up charging to the charging controller **540** when it is determined that the charger **500** is in a condition to start up charging where the charger **500** is electrically connected with the external power source so that voltage is applied to the input side of the charger **500**. On the other hand, when it is determined that the battery **100** is in a full charged state based on the battery state signal output from the controller of the battery **100**, the vehicle controller **840** outputs a command signal to stop the charging to the charging controller **540**. Such an operation may be performed by the motor controller **340**, by the controller of the battery **100** or by the charging controller **540** itself in cooperation with the controller of the battery **100**.

[0071] The controller of the battery **100** detects the state of the battery **100** and calculates an allowable charge amount of the battery **100** and outputs a signal relating to the result of the calculation to the charger **500** in order to control the charging of the battery **100** by the charger **500**.

[0072] The drive circuit **530** is an electronic circuit unit that is constructed by a plurality of electronic components such as switching semiconductor devices or amplifiers on a circuit board. The drive circuit **530** generates drive signals to a plurality of switching semiconductor devices of the booster circuit **520** in response to the command signal output from the charging controller **540**, and outputs the generated drive signals to the gate electrodes of the plurality of the switching semiconductor devices.

[0073] In a case that the alternate current-direct current conversion circuit **510** is constructed by a switching semiconductor device, a switch command signal for the switching semiconductor device of the alternate current-direct current conversion circuit **510** is output to the drive circuit **530**. The drive circuit **530** outputs a drive signal for the switching semiconductor device of the alternate current-direct current

conversion circuit **510** to the gate electrode thereof to control switching of the switching semiconductor device of the alternate current-direct current conversion circuit **510**.

[0074] The first and second positive electrode side relays **410**, **430** and the first and second negative electrode side relays **420**, **440** are accommodated inside the junction box **410**.

[0075] The first positive electrode side relay **410** is a switch to control electrical connection between the direct current positive electrode side of the inverter **300** (power module **310**) and the positive electrode side of the battery **100**. The first negative electrode side relay **420** is a switch to control electrical connection between the direct current negative electrode side of the inverter **300** (power module **310**) and the negative electrode side of the battery **100**. The second positive electrode side relay **430** is a switch to control electrical connection between the direct current positive electrode side of the charger **500** (booster circuit **520**) and the positive electrode side of the battery **100**. The second negative side relay **440** is a switch to control electrical connection between the direct current negative electrode side of the charger **500** (booster circuit **520**) and the negative electrode side of the battery **100**.

[0076] The first positive electrode side relay **410** and the first negative electrode side relay **420** are closed when the system is in an operation mode where the rotative power of the motor generator **200** is required and in an operation mode where electric power generation is required. They are opened when abnormality occurs in the electric-motor driving system or the vehicle and when the battery **100** is charged by the charger **500**. On the other hand, the second positive electrode side relay **430** and the second negative electrode side relay **440** are closed when the battery **100** is charged by the charger **500**. They are opened when the charging of the battery **100** is completed and when abnormality occurs in the charger **500** or the battery **100**.

[0077] Open-close of the first positive electrode side relay **410** and the first negative electrode side relay **420** is controlled by an open-close command signal output from the vehicle controller **840**. The open-close of the first positive electrode side relay **410** and the first negative electrode side relay **420** may be controlled by an open-close command signal output from other controller, for example, the motor controller **340** or the controller of the battery **100**. The open-close of the second positive electrode relay **430** and the second negative electrode side relay **440** is controlled by an open-close command signal output from the charging controller **540**. The open-close of the second positive electrode side relay **430** and the second negative electrode side relay **440** may be controlled by an open-close command signal output from other controller, for example, the vehicle controller **840** or the controller of the battery **100**.

[0078] As mentioned above, in EV **1000**, the first positive electrode side relay **410**, the first negative electrode side relay **420**, the second positive electrode side relay **430**, and the second negative electrode side relay **440** are provided between the battery **100** and the inverter **300** and between the battery **100** and the charger **500**. As a result, high safety of the electric-motor driving system that is at a high voltage can be secured.

[0079] Now, a heat cycle system installed in EV **1000** is explained.

[0080] EV **1000** includes as heat cycle systems an air-conditioning system that controls the condition of air in the

vehicle interior and a temperature control system that controls the temperature of a heat-generating body such as the battery **100**, the motor generator **200**, and the inverter **300**.

[0081] An energy source is required for operating the air-conditioning system and the temperature control system. To this end, EV **1000** uses the battery **100** in the motor generator **200** as such an energy source. Note that the air-conditioning system and the temperature control system consume more electrical energy from the battery **100** than other electrical loads do.

[0082] EV **1000** attracts high attention to the fact that it gives less (more particularly null) influence on the global environment than hybrid vehicles (hereafter, referred to as "HEV").

[0083] However, EV **1000** is less accepted in the market than HEV, since EV **100** shows a low mileage per one charging of the battery **100**, and moreover since promoting of infrastructure such as charging stations is still on the way. Further, EV **1000** consumes much more electrical energy for a desired travel distance than is required by a HEV, so that the battery **100** should have a larger capacity than that of HEV. As a result, the cost of the battery **100** is higher for EV **1000** than for HEV, resulting in a higher cost of the vehicle than HEV. Therefore, EV **1000** is less accepted in the market than HEV.

[0084] In order for EV **1000** to be more accepted in the market, it is necessary to increase the mileage per one charging of the battery **100** of EV. To increase the mileage per one charging of the battery **100** of EV, it is necessary to suppress consumption of electrical energy stored in the battery **10**.

[0085] The heat-generating bodies such as the battery **100**, the temperatures of motor generator **200** and inverter **300** are controlled so that these temperatures fall within allowable temperature ranges. The heat-generating bodies abruptly change their outputs corresponding to a variation in load of EV **1000** and accordingly the amount of generated heat is varied. To operate a heat-generating body with high efficiency, it is desirable to vary the performance of the temperature control system according to variation of heat generation (temperature) of the heat-generating body so that the temperature of the heat-generating body will be maintained always at an optimum temperature.

[0086] On the other hand, in order for EV **1000** to be more accepted in the market, it is necessary to reduce cost of heat-generating bodies such as battery **100**, motor generator **200**, and inverter **300** to lower the price of the vehicle comparable to that of a HEV. To lower the cost of the heat-generating body, it is necessary to reduce the size of and increase the output of the heat-generating body. However, if the heat-generating body has a reduced size and an increased output, the amount of heat generation (temperature) increases, so that it is necessary to increase the performance of the temperature control system for the temperature control of the heat-generating body.

[0087] In the embodiment described below, within a heat cycle system of EV **1000**, a temperature control system and an air-conditioning system are integrally constructed, in order for heat energy to be efficiently used for interior air-conditioning and for temperature control of the heat-generating body.

[0088] Specifically, the heat cycle is divided into a primary heat cycling that exchanges heat with exterior and a secondary heat cycling that exchanges heat with interior and the heat-generating body. The primary heat cycling is constructed by a refrigeration cycle system and the secondary

heat cycle circuit is constructed by two heat transfer systems, each of which has an independently circulating heat medium. In order to allow the refrigerant of the refrigeration cycle system and each heat medium of the two heat transfer systems can exchange heat therebetween, an intermediate heat exchanger is provided between the refrigeration cycle system and each of the two heat transfer systems. Further, in order that the heat medium of the heat transfer system that exchanges heat with the heat-generating body and air taken into the vehicle interior can exchange heat therebetween, an interior heat exchanger is provided in the heat transfer system that exchanges heat with the heat-generating body.

[0089] According to the embodiment described below, the heat energy obtained through temperature control of the heat-generating body can be utilized for interior air-conditioning to minimize energy required for the interior air-conditioning, so that it is possible to save energy for interior air-conditioning. In addition, according to the embodiment described below, the heat energy obtained through temperature control of the heat-generating body can be utilized for the interior air-conditioning, so that the energy saving effect of the interior air-conditioning can be enhanced. Therefore, according to the embodiment described below, the air-conditioning system can reduce energy that the air-conditioning system takes out of the energy source of the heat-generating body.

[0090] The air-conditioning system for a vehicle as mentioned above is suitable for increasing the travel distance of EV **1000** per one charging of the battery **100**. The air-conditioning system for a vehicle as mentioned above is suitable for reducing the capacity of the battery **100** when the travel distance per one charging of the battery **100** is equivalent to that of the conventional one. If the capacity of the battery **100** is reduced, it may lead to a reduction in cost of EV **1000**, helping promotion of EV **1000** in the market, and a reduction in weight of EV **1000**.

[0091] According to the embodiment described below, the heat energy used for interior air-conditioning can be utilized for temperature control of the heat-generating body to control the temperature of the heat medium for temperature control of the heat-generating body to control in a wide range, so that the temperature of the heat-generating body can be changed without being adversely affected by the surrounding environment. Therefore, according to the embodiment described below, the temperature of the heat-generating body can be controlled to be an optimum temperature at which the heat-generating body can operate with high efficiencies, so that it is possible to operate the heat-generating body with high efficiencies.

[0092] The heat cycle system as mentioned above is suitable for reducing the cost of EV **1000**. If EV **1000** is made to be low-cost, it may facilitate EV **1000** to be more widely used.

[0093] As mentioned above, when installing in EV **1000** the heat cycle system that includes a temperature control system and an air-conditioning system in an integrated fashion, it may be expected that the piping that constitutes flow paths and the components are arranged within a narrow installation space in a complicated manner. Taking into consideration maintainability and necessary size and cost reduction for the heat cycle system, and so on, it is desirable to simplify the construction of the system by size reducing, number decreasing or sharing of components when installing the heat cycle system in EV **1000**.

[0094] Accordingly, in the embodiments explained below, a circulation path of a first heat transfer system in which a heat

medium for controlling the temperature of the heat-generating body circulates, which is thermally connected to the refrigeration cycle system in which the refrigerant is circulated through a first intermediate heat exchanger and a circulation path of a second heat transfer system in which a heat medium for controlling the air condition in the vehicle interior is circulated, which are thermally connected to the refrigeration cycle system through a second intermediate heat exchanger, are made to communicate with each other, and a reservoir tank for regulating the pressure in the circulation path of the first and second heat transfer systems is provided such that it is common to both the first and second heat transfer systems.

[0095] According to the embodiments explained below, the components can be made common to the first and second heat transfer systems, so that the heat cycle system can be simplified in construction. The simplification of the construction of the heat cycle system improves maintainability of the heat cycle system installed in EV **1000** and contributes to size reduction and cost reduction of the heat cycle system.

[0096] According to the embodiments explained below, a drainage mechanism for draining heat medium that flows through the circulation paths of the first and second heat transfer systems is provided in common to the first and second heat transfer systems.

[0097] According to the embodiments explained below, the heat cycle system can be further simplified by providing more components to be common to the first and second heat transfer systems, improving the maintainability of the heat cycle system installed in EV **1000** can be further improved, and further contributing to size reduction and cost reduction of the heat cycle system.

[0098] In the case of EV **1000** having installed therein the heat cycle system, when a further size reduction and a further increase in output power of the heat-generating body are required, it is necessary to further increase the performance of the system to cool the heat-generating body in order to cope with the requirement. In this case, as an alternative, it may be considered to further increase in performance of the system to cool the heat-generating body by additional heat exchangers or by increasing the capacity of the heat exchanger. However, taking into consideration necessity of the size and cost reduction, it is desirable that the further increase in performance is achieved without additional heat exchangers or increase in capacity of the heat exchanger.

[0099] To this end, according to the embodiments explained below, the heat cycle system comprises a circulation path connection controller, such that the circulation path of a first heat transfer system, which is thermally connected via a first intermediate heat exchanger to the refrigeration cycle system with the refrigerant circulated therein and in which a heat medium for controlling the temperature of the heat-generating body is circulated, and the circulation path of a second heat transfer system, which is thermally connected to the refrigeration cycle system through a second intermediate heat exchanger and in which a heat medium for controlling the air condition in the vehicle interior is circulated, can be connected in series to each other. When it is requested to make the heat exchange amount of the heat medium supplied to the heat-generating body larger than the heat exchange amount of the heat medium with the refrigerant by one intermediate heat exchanger, the connection of the circulation paths of the first and second heat transfer systems is controlled by the circulation path connection controller such that

the heat medium supplied to the heat-generating body flows through the first and second intermediate heat exchangers in series.

[0100] Furthermore, according to the embodiments explained below, the heat cycle system comprises a first heat transfer system, which is thermally connected via a first intermediate heat exchanger with the refrigeration cycle system in which the refrigerant is circulated and in which a heat medium for controlling the temperatures of at least two heat-generating bodies is circulated; a second heat transfer system, which is thermally connected via a second intermediate heat exchanger to the refrigeration cycle system and in which the heat medium for controlling the air condition in the vehicle interior is circulated; and a circulation paths connection switching unit that connects a connection path of the first heat transfer system to one of the at least two heat-generating bodies and a connection path of the second heat transfer system to another of the at least two heat-generating bodies. When it is desired to make the heat exchange amount between the at least two heat-generating bodies and the heat medium larger than the heat exchange amount between the at least two heat-generating bodies and the heat medium in the first heat transfer system, the connection of the connection paths of the first and second heat cycle systems is switched by the circulation paths connection switching unit so that the heat medium of the first heat transfer system is supplied to one of the heat-generating bodies and the heat medium of the second heat transfer system is supplied to another of the heat-generating bodies.

[0101] According to the embodiments explained below, the heat exchange amount between the heat-generating bodies can be increased, so that the performance of the system for temperature control of the heat-generating bodies can be enhanced. With enhancement of the performance of temperature control of the heat-generating bodies is enhanced as mentioned above, when a further size reduction and a further increase in output are demanded, it is possible to satisfy such a demand. Moreover, the demand is accommodated without an increase in size of the air-conditioning system for a vehicle.

[0102] In the case of EV **1000** shown in FIG. 3, explanation is made on an example in which the motor generator **200** and the inverter **300** are separate. However, the motor generator **200** and the inverter **300** may be integrated into one body, for example, by fixing the casing of the inverter **300** on the casing of the motor generator **200** to integrate them. In case where the motor generator **200** and the inverter **300** are integrated, arrangement of the piping in which heat medium for temperature control flows becomes easier, so that the heat cycle system can be constructed more simply.

[0103] There are some other technical problems and constructions or methods as solutions thereto. These are explained in the embodiments that follow.

[0104] Hereafter, explanation is made on first to fifth embodiments of the heat cycle system that is installed in EV **1000** with reference to the attached drawings.

First Embodiment

[0105] A first embodiment of the heat cycle system **1** installed in EV **1000** is explained referring to FIGS. 1 and 2.

[0106] The heat cycle system **1** includes a refrigeration cycle system **10** of a heat-pump type, a cooling heat transfer system **20**, and an air-conditioning heat transfer system **30**. In the refrigeration cycle system **10** is formed a refrigerant cir-

circulation channel (primary circulation channel) 11, which is configured to circulate a refrigerant, for example, HFC-134a, and condense, expand and evaporate the refrigerant. In the cooling heat transfer system 20 is formed a cooling heat medium circulation channel (secondary channel) 21, which is thermally connected with the refrigeration cycle system 10 via a cooling intermediate heat exchanger 40 and which circulates a cooling heat medium, for example, water or a non-freezing solution so as to exchange heat with the heat-generating body 22 in EV 1000. In the air-conditioning heat transfer system 30 is formed an air-conditioning heat medium circulation channel (secondary channel) 31, which is thermally connected with the refrigeration cycle system 10 via the air-conditioning intermediate heat exchanger 50 and which circulates an air-conditioning heat medium, for example, water or a non-freezing solution so as to exchange heat with the air that is introduced into the vehicle interior.

[0107] The refrigeration cycle system 10 is constructed by the compressor 12, the four-way valve 13, the exterior heat exchanger 14, the expansion valves 15, 16, 17, the cooling intermediate heat exchanger 40, and the air-conditioning intermediate heat exchanger 50, mechanically connected to each other via the refrigeration circulation channel 11.

[0108] A first connection port of the four-way valve 13 is connected to the intake side of the compressor 12. A second connection port of the four-way valve 13 is connected to the discharge side of the compressor 12. A third connection port of the four-way valve 13 is connected to an end of the exterior heat exchanger 14 on the side of the compressor 12. An end of the exterior heat exchanger 14 opposite to the four-way valve 13 is connected the expansion valve 15. The refrigerant circulation channel 11 on the side of the expansion valve 15 opposite to the exterior heat exchanger 14 is, on its extension, branched into a cooling channel 11a and an air-conditioning channel. To this end, to the side of the expansion valve 15 opposite to the exterior heat exchanger 14 are connected the expansion valve 16 for the cooling channel 11a and the expansion valve for the air-conditioning channel 11b, respectively. The side of the expansion valve 16 opposite to the expansion valve 15 is connected to the side of the cooling intermediate heat exchanger 40 opposite to the compressor 12. The side of the expansion valve 17 opposite to the expansion valve 15 is connected to the side of the air-conditioning intermediate heat exchanger 50 opposite to the four-way valve 13. The side of the cooling intermediate heat exchanger 40 opposite to the expansion valve 16 is connected to the intake side of the compressor 12. The side of the air-conditioning intermediate heat exchanger 50 opposite to the expansion valve 17 is connected to a fourth connection port of the four-way valve 13. To the exterior heat exchanger 14 is attached an exterior fan 14a, which is an electric motor-driving type air blower.

[0109] With this connection construction, there are formed a first closed circuit including the compressor 12, the four-way valve 13, the exterior heat exchanger 14, the expansion valve 15, the expansion valve 16, the cooling intermediate heat exchanger 40, and the compressor 12 that are connected in order circularly and a second closed circuit including the compressor 12, the four-way valve 13, the exterior heat exchanger 14, the expansion valve 15, the expansion valve 17, the air-conditioning intermediate heat exchanger 50, the four-way valve 13, and the compressor 12 that are connected in order circularly.

[0110] The compressor 12 is an electric-motor-driving type fluid device that converts the refrigerant into a gaseous medium having a high temperature and a high pressure. The four-way valve 13 is a switch for switching the direction of flow of the refrigerant that is taken in and discharged from the compressor 12. The four-way valve 13 switches the direction of flow of the refrigerant between a direction along which the refrigerant is taken in from the side of the cooling intermediate heat exchanger 40 and the air-conditioning intermediate heat exchanger 50 and discharged to the side of the exterior heat exchanger 14 and a direction along which the refrigerant is taken into the compressor 12 from the side of the exterior heat exchanger 14 and the cooling intermediate heat exchanger 40 and discharged to the side of the air-conditioning intermediate heat exchanger 50. The exterior heat exchanger 14 is a heat transfer device that transfers heat from a higher temperature side medium to a lower temperature side medium between the air (external air) that is blown in by the exterior fan 14a and the refrigerant. The expansion valves 15, 16, 17 control the pressure and the flow rate of the refrigerant by decompressing the refrigerant by controlling the opening of the valve body to expand. The cooling intermediate heat exchanger 40 is a heat transfer device that transfers heat from a higher temperature side medium to a lower temperature side medium between the refrigerant of the refrigeration cycle system 10 and the cooling heat medium of the cooling heat transfer system 20. The air-conditioning intermediate heat exchanger 50 is a heat transfer device that transfers heat from a higher temperature medium to a lower temperature medium.

[0111] The cooling heat transfer system 20 is constructed by the cooling interior heat exchanger 23, the heat-generating body 22, the reservoir tank 24, the circulation pump 25, the cooling intermediate heat exchanger 40, and the three-way valve 26 that are mechanically connected via the cooling heat medium circulation channel 21.

[0112] One side (a side on which the cooling heat medium flows out) of the cooling intermediate heat exchanger 40 is connected the first connection port of the three-way valve 26. The second connection port of the three-way valve 26 is connected to the side of the cooling interior heat exchanger 23 opposite to the heat-generating body 22. The side of the cooling interior heat exchanger 23 opposite to the three-way valve 26 (a side on which the cooling heat medium flows out) is connected to the heat-generating body 22. On a side of the heat-generating body 22 opposite to the cooling interior heat exchanger 23 is connected with the intake side of the circulation pump 25. A side of the circulation pump 25 opposite to the heat-generating body 22 (discharge side) is connected with the other side of the cooling heat exchanger 40 (a side on which the cooling heat medium flows in). Between the cooling interior heat exchanger 22 and the heat-generating body 22 and between the cooling interior heat exchanger 23 and the third connection port of the three-way valve 26 is connected with a bypass route 21a that circulates the cooling heat medium by bypassing the cooling interior heat exchanger 23. To the cooling interior heat exchanger 23 is attached an interior fan 23a. The interior fan 23a is an electric motor-driven air blower for taking in air introduced into the vehicle interior, that is, air in the vehicle interior (internal air) or air taken in from the exterior (external air). Between the heat-generating body 22 and the circulation pump 25 is connected with the reservoir tank 24.

[0113] With this connection construction, the circulation pump 25, the cooling intermediate heat exchanger 40, the three-way valve 26, the cooling interior heat exchanger 23, the heat-generating body 22, and the circulation pump 25 are connected in order in circularly. There are formed the first closed circuit and the second closed circuit, the second closed circuit being constituted by the circulation pump 25, the cooling intermediate heat exchanger 40, the three-way valve 26, the bypass route 21a, the heat-generating body 22, and the circulation pump 25 that are connected in order in a cyclic pattern are formed.

[0114] The cooling interior heat exchanger 23 is a heat transfer device for transferring heat from a higher temperature medium to a lower temperature medium between the cooling heat medium circulating in the cooling heat medium circulation channel 21 and the interior air taken in by the interior fan 23a or external air taken in by the interior fan 23a. The circulation pump 25 is an electric motor-driving type fluid device for circulating the cooling heat medium in the cooling heat medium circulation channel 21. The three-way valve 26 is a switch that switches between the circulation channels of the cooling heat medium by switching the valve body.

[0115] The reservoir tank 24 is to control a variation in the pressure in the cooling heat medium circulation channel 21 following a variation in temperature of the cooling heat medium. The reservoir tank 24 pools excessive cooling heat medium in case that the pressure in the cooling heat medium circulation channel 21 is elevated due to an increase in the cooling heat medium. On the other hand, in case that the temperature of the cooling heat medium is lowered to reduce the pressure in the cooling heat medium circulation channel 21, the cooling heat medium pooled in the reservoir tank 24 is returned to the cooling heat medium circulation channel 21. With such an operation, the pressure in the cooling heat medium circulation channel 21 is maintained always at a specified value.

[0116] The heat-generating body 22 indicates a component of the electric motor-driving system in EV 1000. For example, the battery 100, the motor generator 200, and the inverter unit 300 correspond thereto and are objects of temperature control with the cooling heat medium. The heat-generating bodies 22, which are objects of temperature control, include an electric power converting unit other than the inverter 300, for example, a DC/DC converter installed in the charger 500 or the gearbox of the transmission.

[0117] Here, it is desirable that the heat-generating bodies 22 are arranged in series between the cooling interior heat exchanger 23 and the circulation pump 25 such that the heat-generating bodies 22 are arranged in an increasing order of allowable temperature or in an increasing order of thermal time constant from the upstream side (low temperature state). For example, the battery 100, the inverter unit 300, and the motor generator 200 are arranged in this order. The heat-generating bodies 22 may be arranged between the cooling interior heat exchanger 23 and the circulation pump 25 such that the battery 100, the inverter unit 300 and the motor generator 200 are arranged in parallel to each other.

[0118] Though the heat-generating bodies 22 are arranged between the cooling interior heat exchanger 23 and the circulation pump 25, they may be arranged between the cooling intermediate heat exchanger 50 and the three-way valve 26.

[0119] The air-conditioning heat transfer system 30 is constructed by the air-conditioning interior heat exchanger 32,

the circulation pump 33 and the air-cooling intermediate heat exchanger 50 that are mechanically connected with each other through the air-conditioning heat medium circulation channel 31.

[0120] On one side of the air-conditioning intermediate heat exchanger 50 (on the side where the air-conditioning heat medium flows out) is connected with the side of the air-conditioning interior heat exchanger 32 opposite to the circulation pump 33 (on the side where the air-conditioning heat medium flows in). On the side of the air-conditioning interior heat exchanger 32 opposite to the air-conditioning intermediate heat exchanger 50 (on the side where the air-conditioning heat medium flows out) is connected to the intake side of the circulation pump 33. The side (the discharge side) of the circulation pump 33 opposite to the air-conditioning interior heat exchanger 32 is connected to the other side (the side where the air-conditioning heat medium flows in) of the air-conditioning intermediate heat exchanger 50.

[0121] With this connection construction, a closed circuit is formed constructed by the circulation pump 33, the air-conditioning intermediate heat exchanger 50, the air-conditioning interior heat exchanger 32, and the circulation pump 25, connected in order circularly.

[0122] The air-conditioning interior heat exchanger 32 is a heat transfer device that transfers heat from a higher temperature medium to a lower temperature medium between the air-conditioning heat medium circulating in the air-conditioning heat medium circulation channel 31 and the interior air or exterior air taken in by the interior fan 23a. The circulation pump 33 is an electric motor-driving type fluid device that circulates the air-conditioning heat medium in the air-conditioning heat medium circulation path 31.

[0123] The cooling interior heat exchanger 23 and the air-conditioning interior heat exchanger 32 are arranged in the order of the air-conditioning interior heat exchanger 32 and the cooling interior heat exchanger 23 in the direction of from the upstream side toward the downstream side of the flow of internal air or external air. The cooling interior heat exchanger 23 and the air-conditioning interior heat exchanger 32 have the interior fan 23a in common. The interior fan 23a is arranged on the downstream side of the cooling interior heat exchanger 23 and the air-conditioning interior heat exchanger 32 with respect to the flow of the interior air or the exterior air.

[0124] Between the cooling interior heat exchanger 23 and the air-conditioning interior heat exchanger 32 is provided a communication path 60. The communication path 60 is provided in order to perform control of the pressure in the air-conditioning heat medium circulation channel 31 corresponding to a temperature variation of the air-conditioning heat medium with the reservoir tank 24 connected to the cooling heat medium circulation channel 21. That is, the cooling heat transfer system 20 and the air-conditioning heat transfer system 30 have the reservoir tank 24 in common. In case that the temperature of the air-conditioning heat medium becomes relatively high to increase the pressure in the air-conditioning heat medium circulation channel 31, excessive air-conditioning heat medium is discharged from the air-conditioning heat exchange circulation channel 31 via the communication path 60 and accumulated in the reservoir tank 24. Here, the air-conditioning heat medium and the cooling heat medium are the same and comprise water or a non-freezing solution. In case that the temperature of the air-conditioning heat medium is lowered to reduce the pressure in the air-conditioning heat medium circulation channel 31, the

accumulated air-conditioning heat medium is returned from the reservoir tank 24 to the air-conditioning heat medium circulation channel 31 via the cooling heat medium circulation channel 21 and the communication path 60. With this operation, the pressure in the air-conditioning heat medium circulation channel 31 is maintained always at a specified value.

[0125] Since the cooling heat transfer system 20 and the air-conditioning heat transfer system 30 have the reservoir tank 24 in common according to the present embodiment as mentioned above, the number of components of the heat cycle system 1 can be reduced, so that the construction of the heat cycle system 1 can be simplified. The simplified construction of the heat cycle system 1 improves the maintainability of the heat cycle system 1, in which the piping constituting the channels and components could be arranged in a complicated manner in a narrow installation space, and contributes to downsizing and a reduction in cost of the heat cycle system 1.

[0126] The reservoir tank 24 may be provided in the air-conditioning heat medium circulation channel 31. In the example shown in FIG. 1, the reservoir tank 24 is provided between the heat-generating body 22 and the circulation pump 25. However, it may be arranged in other areas on the cooling heat medium circulation channel 21.

[0127] According to the present embodiment, a drainage mechanism for draining the cooling heat medium that flows in the cooling heat medium circulation channel 21 and the air-conditioning heat medium that flows in the air-conditioning heat medium circulation channel 31 to the exterior is provided at the lowest position of the cooling heat medium circulation channel 21. According to the present embodiment, the drainage mechanism is provided between the reservoir tank 24 on a circulation channel between the reservoir tank 24 and the circulation pump 25 in the cooling heat medium circulation channel 21. The drainage mechanism is constructed by a drainage path 70 connected to the circulation channel between the reservoir tank 24 and the circulation pump 25 in the cooling heat medium circulation channel 21 and a drainage on-off valve 71. The drainage on-off valve 71 is opened when the cooling heat medium circulating in the cooling heat medium circulation channel 21 and the air-conditioning heat medium circulating in the air-conditioning circulation channel 31 are exchanged therebetween. The air-conditioning heat medium circulating in the air-conditioning circulation channel 31 is drained to the cooling heat medium circulation channel 21 via the communication path 60 and then discharged to the exterior by the drainage mechanism. To this end, the communication path 60 communicates the cooling heat medium circulation channel 21 and the air-conditioning heat medium circulation channel 31 therebetween at their lowest positions.

[0128] With the above-mentioned construction, the number of components of the heat cycle system 1 can be further decreased, so that the construction of the heat cycle system 1 can be further simplified. This can further improve maintainability of the heat cycle system 1 and contribute to downsizing and cost reduction of the heat cycle system 1.

[0129] Now, the operational actions of the heat cycle system 1 are explained for each operation mode.

[0130] (Air-Cooling Operation)

[0131] Air-cooling operation means an operation mode in which there is performed air-cooling of the vehicle interior with air-conditioning heat transfer system 30 constructed by the exterior heat exchanger 14 as a condenser, the air-conditioning intermediate heat exchanger 50 and the cooling intermediate heat exchanger 40 as evaporators as well as cooling

system 20. In the case of the air-cooling operation, as shown in FIG. 1, the discharging side of the compressor 1 is connected to the exterior heat exchanger 14 via the four-way valve 13 provided in the refrigeration cycle system 10, and the intake side of the compressor 12 is connected to the air-conditioning intermediate heat exchanger 50. To the intake side of the compressor 12 is connected the cooling intermediate heat exchanger 50. The cooling heat medium is circulated in the bypass route 21a through the three-way valve 26.

[0132] The refrigerant compressed by the compressor 12 to become gaseous refrigerant at high temperature and high pressure exchanges heat with external air (radiates heat) to be liquefied. Then the refrigerant passes through the expansion valve that is in a full opened state and then divided in the receiver 24 into a portion of the refrigerant that flows into the air-conditioning intermediate heat exchanger 50 and a portion of the refrigerant that flows into the cooling intermediate heat exchanger 40. The portion of the refrigerant that flows into the air-conditioning intermediate heat exchanger 50 is decompressed by the expansion valve 17 to have a lower temperature and a lower pressure. The refrigerant having a lower temperature and a lower pressure absorbs, in the air-conditioning intermediate heat exchanger 50, heat from the air-conditioning heat medium of the air-conditioning heat medium circulation path 31 to be evaporated, and is returned to the compressor 12 via the four-way valve 13. On the other hand, the portion of the refrigerant that is flown to the cooling intermediate heat exchanger 40 is decompressed by the expansion valve 16 to become a refrigerant having a lower temperature and a lower pressure. The refrigerant having a lower temperature and a lower pressure absorbs, in the cooling intermediate heat exchanger 40, heat from the cooling heat medium of the cooling heat medium circulation channel 21 to be evaporated and is returned to the compressor 12.

[0133] By driving the circulation pump 33 provided in the air-conditioning heat medium circulation channel 31, the air-conditioning heat medium that is cooled due to heat exchange at the air-conditioning intermediate heat exchanger 50 is supplied to the air-conditioning interior heat exchanger 32. The air-conditioning heat medium exchanges heat with air introduced to the interior by driving the interior fan 23a in the air-conditioning interior heat exchanger 32, i.e., the heat of air is radiated to the air-conditioning heat medium.

[0134] When the circulation pump 25 provided in the cooling heat medium circulation channel 21 is driven, the cooling heat medium cooled at the cooling intermediate heat exchanger 40 is supplied to the heat-generating body 22 via the bypass route 21a. The cooling heat medium exchanges heat with the heat-generating body 22, i.e., the heat of the heat-generating body 22 is radiated to the cooling heat medium. As a result, the heat-generating body 22 is cooled.

[0135] Since according to the present embodiment, both the air-conditioning intermediate heat exchanger 50 and the cooling intermediate heat exchanger 40 can be used as evaporators as mentioned above, the air-cooling of the vehicle interior and the cooling of the heat-generating body 22 can be achieved simultaneously. Furthermore, since the air-conditioning intermediate heat exchanger 50 and the cooling intermediate heat exchanger 40 are parallel connected to the intake side of the compressor 12 in parallel and the expansion valves 16, 17 are provided in the cooling channel 11a and the air-

conditioning channel 11*b*, respectively, flow rates of the portions of the refrigerant that flow in the air-conditioning intermediate heat exchanger 50 and the cooling intermediate heat exchanger 40 can be changed freely. As a result, the temperature of the cooling heat medium and the temperature of the air-conditioning heat medium can be controlled to be at any setup temperatures. Therefore, even when the temperature of the air-conditioning heat medium is sufficiently lowered in order to perform air-cooling, the temperature of the cooling heat medium to which the heat-generating body 22 is connected can be maintained high by suppressing the flow rate of the portion of the refrigerant that flows into the cooling intermediate heat exchanger 40.

[0136] When the surface temperature of the heat-generating body 22 becomes lower than the temperature of the external air, heat is transferred from the external air to the heat-generating body 22. Therefore, the cooling performance required of the refrigeration cycle system 10 increases by an amount that corresponds to the amount of heat gained, which will increase power consumption. This results in an increase in use amount of the electricity from the battery 100, leading to a decrease in travel distance. In case that the temperature of the heat-generating body 22 is lower than the dew point of the external air, there is the possibility that dew formation will occur, so that countermeasures against troubles caused by the dew formation become necessary. Since such a technical problem will do for the piping route, it is desirable that the temperature of the cooling heat medium is maintained higher than the temperature of the external air.

[0137] The temperature of the cooling heat medium can be controlled by controlling the opening of the expansion valve 16. In a simplified case, the valve is relatively more opened when the temperature of the cooling heat medium is relatively high and the valve is relatively more closed when that temperature is relatively low.

[0138] The performance of the refrigeration cycle circuit 10 can be controlled by regulating the rotational speed of the compressor 12 such that the temperature of the air-conditioning heat medium reaches a setup temperature. When it is determined that the load of air-cooling is high, the target temperature of the air-conditioning heat medium is lowered whereas when it is determined that the load of air-cooling is low, the target temperature of the air-conditioning heat medium is elevated. By so doing, control of the air-conditioning performance corresponding to the load can be achieved.

[0139] When no load of air-cooling is imposed and only cooling of the heat-generating body 22 is required, it is necessary to use only the cooling intermediate heat exchanger 40 as an evaporator by stopping the circulation pump 33 and the interior fan 23*a* and closing the expansion valve 17 and controlling the opening of the expansion valve 16. This makes it possible to cool the cooling heat medium, so that the heat-generating body 22 can be cooled. In this case, the rotational speed of the compressor 12 is controlled so that the temperature of the cooling heat medium reaches the target temperature. In this case, the target temperature is set at a temperature higher than the temperature of the external air. Also, the heat exchange amount may be changed by controlling the rotational speed of the circulation pump 25.

[0140] (Air-Cooling/Dehumidifying Operation)

[0141] In an air-cooling/dehumidifying operation, the two-way valve 26 is opened from the state shown in FIG. 1 to allow the cooling heat medium at a high temperature to flow into the side of the cooling interior heat exchanger 23. When the t

cooling heat medium 41 B having a high temperature is introduced in the cooling interior heat exchanger 23 as mentioned above, it is possible to perform a so-called reheating and dehumidifying operation in which the air that is cooled and dehumidified at the air-conditioning interior heat exchanger 32, after being heated at the cooling interior heat exchanger 23, is blown into the vehicle interior. Since the air supplied to the vehicle interior has a lower relative humidity, comfortableness of the interior space can be improved.

[0142] The heat source of the cooling interior heat exchanger 23 used as a reheater is a so-called waste heat that is generated by the heat-generating body 22. Therefore, unlike the case where a heater or the like is used for reheating, it is unnecessary to additionally introduce energy, so that the comfortableness of the vehicle interior can be improved without increasing power consumption.

[0143] The amount of reheat may vary depending on the temperature and flow rate of the portion of the cooling heat medium that flows to the side of the cooling interior heat medium 23. Accordingly, the reheat can be controlled by varying the heat exchange amount at the cooling intermediate heat exchanger 40 or the flow rate of the portion of the cooling heat medium that flows out to the side of cooling interior heat exchanger 23. In order to make variable the heat exchange amount of the cooling intermediate heat exchanger 40, the opening of the expansion valve 16 may be controlled to control the flow rate of the portion of the refrigerant that flows into the cooling intermediate heat exchanger 40. When no cooling is necessary, the expansion valve 16 may be fully closed.

[0144] In order to make variable the flow rate of the portion of the cooling heat medium that flows into the cooling interior heat exchanger 23, the open-close state of the three-way valve 26 may be controlled.

[0145] (Air-Heating Operation)

[0146] Next, the actions at the time of air-heating operations are explained referring to FIG. 2.

[0147] The air-heating operation can be performed in two operation modes depending on the load of air-heating.

[0148] A first operation mode is a heat-radiating operation mode when the load of air-heating is low and uses the heat released from the heat-radiating body 22 without using the refrigeration cycle system 10 for air-heating. In the heat-radiating operation mode, the circulation pump 25 and the interior fan 23*a* are started up and the two-way valve 26 is opened to introduce the cooling heat medium into the cooling interior heat exchanger 23. Since the cooling heat medium is already heated by the heat-generating body 22, the cooling heat medium will be cooled when it radiates heat to the air to be blown into the vehicle interior at the cooling interior heat exchanger 23 and the air to be blown into the vehicle interior is heated. By utilizing the heat released from the heat-generating body 22 for air-heating, the air-conditioning can be performed with suppressing energy consumption.

[0149] A second operation mode of the air-heating operation is an operation mode when the heat released from the heat-generating body 22 is insufficient for the load of air-heating, i.e., an air-heating/heat-radiating operation mode in which the refrigeration cycle system 10 is used in combination with the heat released from the heat-generating body 22. In this case, the four-way valve 13 provided in the refrigeration cycle system 10 is switched as indicated by a solid line connecting the discharge side of the compressor 12 to the air-conditioning intermediate heat exchanger 50 and the

intake side of the compressor 12 to the exterior heat exchanger 14. That is, there is formed a cycling in which the air-heating intermediate heat exchanger 50 works as a condenser and the exterior heat exchanger 14 as an evaporator.

[0150] The refrigerant compressed by the compressor 12 is condensed and liquefied when it exchanges heat with the air-conditioning heat medium to radiate heat to the air-conditioning heat medium at the air-conditioning intermediate heat exchanger 50. Thereafter, the condensed and liquefied refrigerant is decompressed through the expansion valve 15, evaporated and gasified due to heat exchange with the exterior air at the exterior heat exchanger 14, and returned to the compressor 12. The expansion valve 17 is fully opened and the cooling intermediate heat exchanger 40 is not used.

[0151] By starting up the circulation pump 33, the air-conditioning heat medium warmed with the condensation heat from the refrigerant at the air-conditioning intermediate heat exchanger 50 flows into the air-conditioning interior heat exchanger 32, where the warmed refrigerant releases heat to the air to be blown into the vehicle interior space. The air heated at the air-conditioning interior heat exchanger 32 is flown to the cooling interior heat exchanger 23 that is arranged on the downstream side of the flow of air and gains heat from the cooling heat medium heated by the heat-generating body 22 to be further elevated in temperature and then blown out into the vehicle interior space.

[0152] As mentioned above, the system is constructed such that the air to be blown into the vehicle interior is further heated with the heat released from the heat-generating body 22 after it is heated by the refrigeration cycle system 10. As a result, the temperature of the air blown from the air-conditioning interior heat exchanger 32 can be kept low as compared with the temperature of the air to be blown into the vehicle interior from the cooling interior heat exchanger 23. That is, an air-conditioning apparatus that consumes less energy can be constructed by utilizing heat released from the heat-generating body 22 for air-heating.

[0153] By controlling the air-heating performance of the refrigeration cycle system 10, the temperature of the cooling heat medium can be controlled depending on the amount of heat generated by the heat-generating body 22. When the amount of heat generated by the heat-generating body 22 increases, the temperature of the cooling heat medium increases, and therefore to the air-heating performance of the refrigeration cycle system 10 is decreased. Due to this, the amount of heat released from the air-conditioning interior heat exchanger 32 is decreased, and therefore the temperature of the air that flows into the cooling interior heat exchanger 23 is lowered. Accordingly, the amount of heat radiated from the cooling heat medium increases and the temperature increases, so that the temperature elevation of the cooling heat medium is suppressed.

[0154] Conversely, when the amount of heat generated by the heat-generating body 22 is decreased, the temperature of the cooling heat medium is lowered. Accordingly, the lowering of temperature of the cooling heat medium is suppressed by increasing the air-heating performance of the refrigeration cycle system 10 to increase the temperature of the air that flows into the cooling interior heat exchanger 23.

[0155] As a concrete example of controlling the performance of the refrigeration cycle system 10, controlling the rotational speed of the compressor 12 may be referred to.

[0156] It is effective to control the temperature of the cooling heat medium within a predetermined temperature range

for avoiding a trouble, for example, that the temperature of the heat-generating body deviates from its operational temperature range.

[0157] (Air-Heating/Cooling Operation)

[0158] FIG. 5 is a diagram illustrating an air-heating/cooling operation. As mentioned above, when the load of air-heating is high, the target temperature of the cooling heat medium may be set higher. However, when it is difficult to elevate the target temperature of the cooling heat medium according to, for example, the specification of the heat-generating body 22, the air-heating performance cannot be increased. In such a case, the air-heating/cooling operation as explained below is performed to implement both the cooling of the cooling heat medium and the heating of the air-conditioning heat medium simultaneously.

[0159] In the case of air-heating/cooling operation, like the combined air-heating/heat radiating operation, there is formed a cycling in which the air-conditioning intermediate heat exchanger 50 is used as a condenser and the exterior heat exchanger 14 is used as an evaporator; and additionally the expansion valve 16 is opened to use the cooling intermediate heat exchanger 40 as an evaporator. The refrigerant that is condensed and liquefied at the air-conditioning intermediate heat exchanger 50 is divided into two portions after passing through the expansion valve 17, one of the divided portions of the refrigerant is returned to the compressor 12 after it is decompressed through the expansion valve 23 and evaporated at the exterior heat exchanger 14. The other of the divided portions of the refrigerant is decompressed through the expansion valve 16 and cools the cooling heat medium at the cooling intermediate heat exchanger 40 to be evaporated and gasified, and then returned to the compressor 12 through the three-way valve 21.

[0160] In the air-heating/cooling operation, the heat released from the heat-generating body 22 is recovered at the cooling intermediate heat exchanger 40 as a heat source for the refrigeration cycle system 10, transferred to the air-conditioning interior heat exchanger 32 and released into the vehicle interior from the air-conditioning interior heat exchanger 32 via the air-conditioning intermediate heat exchanger 50. As mentioned above, it is possible to recover the heat released by the heat-generating body 22 and to use the recovered heat for air-heating, while controlling the temperature of the heat-generating body 22. Since it is possible to absorb heat from external air by using the exterior heat exchanger 14, the air-heating performance can be increased.

[0161] It is possible to control the amount of heat absorbed from the cooling heat medium and the amount of heat absorbed from the external air individually by controlling the openings of the expansion valves 16 and 23, respectively.

[0162] When the temperature of the cooling heat medium becomes lower than the temperature of the air-conditioning cooling medium, the air heated at the air-conditioning interior heat exchanger 32 will be cooled at the cooling interior heat exchanger 23. In such a case, the two-way valve 26 is operated in the cooling heat medium circulation channel 21 to divert the cooling heat medium that is cooled at the cooling intermediate heat exchanger 40 to the bypass route 21a. This prevents the air to be blown into the vehicle interior from being cooled by the cooling heat medium.

[0163] In case when the load of air-heating is lowered and the air-heating/cooling operation is changed to a combined air-heating/heat-radiating operation, there is the possibility that there occurs a trouble, for example, that the blowing

temperature becomes low if the temperature of the cooling heat medium is low. Therefore, it is desirable to increase the temperature of the cooling heat medium before the operation mode change. This can be achieved by controlling the opening of the expansion valve 16 since the temperature of the cooling heat medium can be controlled by making variable the amount of heat exchange of the cooling intermediate heat exchanger 40.

[0164] In case when it is detected that the temperature of the air-conditioning cooling medium becomes lower than the temperature of the cooling heat medium while keeping the temperature of the cooling heat medium during the air-heating/cooling operation, the load of air-heating is judged to be decreased, so that the operation mode of the system can be changed from the air-heating/cooling operation to the combined air-heating/heat radiating operation mode.

[0165] (Heating Operation)

[0166] Upon starting up of the system when the external air temperature is low as in winter seasons, the temperature of the cooling heat medium is low so that it cannot be used for air-heating immediately after its starting up and it is necessary to wait for a while until the temperature of the cooling heat medium increases with the heat released from the heat-generating body 22. In such a case, the expansion valve 16 is closed to perform an air-heating operation by using the air-conditioning interior heat exchanger 32. Also, a cycling is constructed in which the heat exchange does not occur at the cooling interior heat exchanger 23 between the cooling heat medium of low temperature and the blown air into the vehicle interior, for which the two-way valve 26 is closed and the two-way valve 25 is opened.

[0167] In case when the temperature of the heat-generating body 22 is lower than the allowable temperature of the lower temperature side, the cooling heat medium is warmed at the cooling intermediate heat exchanger 40, and the warmed cooling heat medium is supplied to the heat-generating body 22 via the three-way valve 26 and the bypass route 21a to warm the heat-generating body 22 in advance immediately before starting up EV 1000. In this case, a start up time is preliminarily set in the startup time setting system, and before a predetermined time prior to the set time the heat cycle system 1 is activated, and the above-mentioned heating operation is performed. By so doing, the heat-generating body 22 can be operated efficiently at the start up of EV 1000, so that EV 1000 can be driven by supplying from the motor generator 200, a torque corresponding to the demanded torque.

Second Embodiment

[0168] A second embodiment of the heat cycle system 1 installed in EV 1000 is explained referring to FIGS. 4 and 5.

[0169] The second embodiment is an improved variation of the first embodiment, in which there is provided a circulation channel connection control unit that can connect in series a portion of the cooling air-conditioning heat medium circulation channel 31 to a portion of the cooling heat medium circulation channel 21 such that the heat medium that flows in the cooling circulation heat medium circulation channel 21 can flow through the air-conditioning intermediate heat exchanger 50 and the cooling intermediate heat exchanger 40 in series.

[0170] Note that the structures similar to those according to the first embodiment are indicated with the same reference numerals as those used in the first embodiment and explanation thereof is omitted.

[0171] The circulation channel connection control unit is constructed by a three-way valve 84, a three-way valve 83, a three-way valve 81, a connection path 82 and a connection path 80. The three-way valve 84 is provided on the circulation path between the circulation pump 25 and the cooling intermediate heat exchanger 40. The three-way valve 83 is provided on the circulation path between the circulation pump 33 and the air-conditioning intermediate heat exchanger 50. The three-way valve 81 is provided on the circulation path between the air-conditioning intermediate heat exchanger 50 and the air conditioning interior heat exchanger 32. The connection path 82 connects between the three-way valve 84 and the three-way valve 83.

[0172] The first connection port of the three-way valve 81 is connected with one side (the side where the air-conditioning heat medium flows out) of the air-conditioning intermediate heat exchanger 50. The second connection port of the three-way valve 81 is connected with a side of the air-conditioning interior heat exchanger 32 on the side (the side where the air-conditioning heat medium flows in) of the air-conditioning intermediate heat exchanger 50. The third connection port of the three-way valve 81 is connected with the connection path 80. The first connection port of the three-way valve 83 is connected with the discharge side of the circulation pump 33. The second connection port of the three-way valve 83 is connected with the other side (the side where the air-conditioning heat medium flows in) of the air-conditioning intermediate heat exchanger 50. The third connection port of the three-way valve 83 is connected with the connection path 82. The first connection port of the three-way valve 84 is connected with the discharge side of the circulation pump 25. The second connection port of the three-way valve 84 is connected to one side, i.e., the discharge side where the cooling heat medium flows in, of the cooling intermediate heat exchanger 40. The third connection port of the three-way valve 84 is connected with the connection path 82.

[0173] In case where it is desired to increase the performance of controlling the temperature of (cooling) the heat-generating body 22 by making the amount of heat exchanged between the cooling heat medium supplied to the heat-generating body 22 and the refrigerant larger than the amount of the heat exchange between the refrigerant and the cooling intermediate heat exchanger 40 alone, the three-way valves 81, 83, 84 for switching the direction of the flow of fluid are driven to switch the direction of flow of the cooling heat medium.

[0174] Here, the case where it is desired to increase the performance of controlling the temperature of (cooling) the heat-generating body 22 is, for example, a case where running on a sloping road that requires high load of the motor is continued; the heat generation by the motor generator or the inverter unit that constitutes the heat-generating body 22 generates more heat, so that their temperature increases. Accordingly, in case that the increase in temperature due to the increase in heat generation exceeds a predetermined acceptable value, the three-way valves 81, 83, 84 may be driven to switch the direction of flow of the cooling heat medium as mentioned above. Such a control is performed, for example, by the vehicle controller 840.

[0175] Here, in case that the heat cycle system 1 is in each of the operation modes as described in the first embodiment (the case shown in FIG. 4), the three-way valves 81, 83, 84 are in a state in which the cooling heat medium does not flow to the connection paths 80, 82, that is, each of them is in a state where the cooling heat medium does not flow in the direction of from the first connection port to the second connection port.

[0176] In case where it is desired to increase the performance of controlling the temperature of (cooling) the heat-generating body 22 by making the amount of heat exchanged between the cooling heat medium supplied to the heat-generating body 22 and the refrigerant larger than the amount of the heat exchange between the refrigerant and the cooling intermediate heat exchanger 40 alone, the switching mechanism of the three-way valves 81, 83, 84 is driven as follows. That is, as shown in FIG. 5, the three-way valves 81, 83, 84 are driven such that the cooling heat medium flows in the direction of from the first connection port to the third connection port of the three-way valve 81, the cooling heat medium flows in the direction of from the third connection port to the second connection port of the three-way valve 83, and the cooling heat medium flows in the direction of from the first connection port to the third connection port of the three-way valve 84. As a result, the cooling heat medium pumped by the circulation pump 25 is fed to the air-conditioning intermediate heat exchanger 50 through the three-way valve 84, the connection path 82, and the three-way valve 83 to exchange heat with the refrigerant of the refrigeration cycle system 10. Thereafter, the cooling heat medium that flows out from the air-conditioning intermediate heat exchanger 50 is fed to the cooling intermediate heat exchanger 40 through the three-way valve 81 and the connection path 80 to exchange heat with the refrigerant again.

[0177] Note that in FIG. 5, the paths in which the cooling heat medium flows are indicated by solid lines and the paths in which no heat medium flows are indicated by broken lines.

[0178] According to the second embodiment, by flowing the cooling heat medium through the air-conditioning intermediate heat exchanger 50 and the cooling intermediate heat exchanger 40 in order in series, the amount of heat exchange between the cooling heat medium and the refrigerant can be made larger than that in the case of the first embodiment, so that the performance of cooling the heat-generating body 22 can be made larger than that in the first embodiment. Therefore, in case that further downsizing and higher output of the heat-generating body is required, such requirement can be met. In addition, this is coped with out concomitant enlargement of the heat cycle system for a mobile object.

[0179] In this case, air-cooling of the vehicle interior becomes impossible. In case where it is desired to perform both the cooling of the heat-generating body and the air-cooling of the vehicle interior simultaneously, two flow control valves instead of the three-way valve 26 may be arranged one on the bypass route 21a and the other on the circulation path leading to the side of the cooling interior heat exchanger 23 to control the flow rates of the cooling heat medium that flows on the side of the cooling interior heat exchanger 23 and of the cooling heat medium that flows in the bypass route 21a, respectively.

Third Embodiment

[0180] A third embodiment of the heat cycle system 1 for a mobile object installed in EV 1000 is explained referring to FIGS. 6 and 7.

[0181] The third embodiment is an improved variation of the first embodiment, in which there is provided a circulation channel connection switch unit that switches such that the cooling heat medium circulation channel 21 can be connected with the heat-generating body 22 and the cooling air-conditioning heat medium circulation channel 31 with a heat-generating body 27 other than the heat-generating body 22. For example, the battery 100 and the inverter unit 300 correspond to the heat-generating bodies 22 and the motor generator 200 corresponds to the heat-generating body 27. As a result, the cooling heat medium that circulates in the cooling heat medium circulation path 21 can be flown to the heat-generating body 22 and separately, the air-conditioning heat medium that circulates in the air-conditioning heat medium circulation path 31 can be flown to the heat-generating body 27.

[0182] The structures similar to those according to the first embodiment are indicated with the same reference numerals as those used in the first embodiment and explanation thereof is omitted.

[0183] The circulation path connection switch unit is constructed by a three-way valve 94, a three-way valve 91, a three-way valve 92, a four-way valve 95, a connection path 90, a connection path 93 and a connection path 96. The three-way valve 94 is provided on a circulation path between the air-conditioning intermediate heat exchanger 50 and the air-conditioning interior heat exchanger 32. The three-way valve 91 is provided on a circulation path between the air-conditioning interior heat exchanger 32 and the circulation pump 33. The three-way valve 92 is provided on a circulation path between the heat-generating body 27 and the circulation pump 25. The three-way valve 95 is provided on a circulation path between the reservoir tank 24 and the heat-generating body 27. The connection path 90 connects between the three-way valve 91 and the three-way valve 92. The connection path 93 connects between the three-way valve 94 and the four-way valve 95. The connection path 96 connects between the circulation path provided between the three-way valve 92 and the circulation pump 25 and the four-way valve 95.

[0184] The first connection port of the three-way valve 94 is connected with one side (the side where the air-conditioning heat medium flows out) of the air-conditioning intermediate heat exchanger 50. The second connection port of the three-way valve 94 is connected with a side of the air-conditioning interior heat exchanger 32 on the side (the side where the air-conditioning heat medium flows in) of the air-conditioning intermediate heat exchanger 50. The third connection port of the three-way valve 94 is connected with the connection path 93. The first connection port of the three-way valve 91 is connected with one side (the side where the air-conditioning heat medium flows out) of the air-conditioning interior heat exchanger 32. The second connection port of the three-way valve 91 is connected with the intake side of the circulation pump 33. The third connection port of the three-way valve 91 is connected with the connection path 90. The first connection port of the three-way valve 92 is connected with a side of the heat-generating body 27 on the side of the circulation pump 25. The second connection port of the three-way valve 92 is connected with the intake side of the circulation pump 25. The second connection port of the three-way valve 92 is connected with the intake side of the circulation pump 25. The third connection port of the three-way valve 92 is connected with the connection path 90. The first connection port of the four-way valve 95 is connected with a side of the reservoir

tank 24 opposite to the side of the heat-generating body 22. The second connection port of the four-way valve 95 is connected with a side of the heat-generating body 27 opposite to the side of the three-way valve 92. The third connection port of the four-way valve 95 is connected with the connection path 93. The fourth connection port of the four-way valve 95 is connected with the connection path 96.

[0185] In case where it is desired to increase the performance of temperature control (cooling) of the heat-generating bodies 22, 27 by making the amount of heat exchanged between the heat-generating bodies 22, 27 and the heat medium (cooling heat medium and the air-conditioning heat medium) larger than that of heat exchanged between the heat-generating bodies and the cooling heat medium, the three-way valves 91, 92, 94 and the four-way valve 95 for switching the directions of the flow of the fluid are driven to switch the directions of the flow of the cooling heat medium and the air-conditioning heat medium.

[0186] Here, the case where it is desired to increase the performance of temperature control (cooling) of the heat-generating body 22 is, for example, a case where running on a sloping road that requires high load of the motor is continued; temperatures of the heat-generating bodies 22, 27 increase considerably. Accordingly, in case that the increase in temperature due to the increase in heat generation exceeds a predetermined acceptable value, the three-way valves 91, 92, 93 and the four-way valve 95 may be driven to switch the directions of the flow of the cooling heat medium and the air-conditioning heat medium as mentioned above. Such a control is performed, for example, by the vehicle controller 840.

[0187] Here, in case that the heat cycle system 1 is in each of the operation modes as described in the first embodiment (the case shown in FIG. 6), the three-way valves 91, 92, 93 and the four-way valve 95 are in a state in which the cooling heat medium does not flow to the connection paths 90, 93, 96, that is, each of them is in a state where the cooling heat medium does not flow in the direction of from the first connection port to the second connection port.

[0188] In case where it is desired to increase the performance of temperature control (cooling) of the heat-generating bodies 22, 27 by making the amount of heat exchanged between the heat-generating bodies 22, 27 and the heat media larger than the amount of the heat exchanged between the heat-generating bodies 22, 27 and the cooling heat medium, the switching mechanism of the three-way valves 91, 92, 93 and the four-way valve 95 is driven as shown in FIG. 7. That is, the switching mechanism is driven such that the air-conditioning heat medium flows in the direction of from the first connection port to the third connection port of the three-way valve 94, the air-conditioning heat medium flows in the direction of from the third connection port to the third connection port of the three-way valve 92, the air-conditioning heat medium flows in the direction of from the third connection port to the second connection port of the three-way valve 91, and the cooling heat medium flows in the direction of from the first connection port to the fourth connection port of the four-way valve 95, and at the same time the air-conditioning heat medium flows from the third connection port to the second connection port of the four-way valve 95. As a result, the cooling heat medium pumped by the circulation pump 25 is fed to the cooling intermediate heat exchanger 40 where it exchanges heat with the refrigerant in the refrigeration cycle system 10. Thereafter, the cooling heat medium that flows out

from the cooling intermediate heat exchanger 40 is fed to the heat-generating body 22 through the three-way valve 26 and the bypass route 21a and exchanges heat with the heat-generating body 22. Thereafter, the cooling heat medium is circulated to the circulation pump 25 through the reservoir tank 24, the four-way valve 95, and the connection path 96. On the other hand, the air-conditioning heat medium pumped by the circulation pump 33 is fed to the air-conditioning intermediate heat exchanger 50 where it exchanges heat with the refrigerant. Thereafter, the air-conditioning heat medium that flows out from the air-conditioning intermediate heat exchanger 50 is fed to the heat-generating body 27 through the three-way valve 94, the connection path 93, and the four-way valve 95 and then circulated to the circulation pump 33 through the three-way valve 92, the connection path 90 and the three-way valve 91.

[0189] Note that in FIG. 7, the paths in which the cooling heat medium flows are indicated by solid lines and the paths in which no heat medium flows are indicated by broken lines.

[0190] According to the third embodiment, by flowing the cooling heat medium to the heat-generating body 22 and the air-conditioning heat medium to the heat-generating body 27, the amount of heat exchange (the amount of cooling of heat medium) between the heat-generating bodies can be made larger than that in the case of the first embodiment, so that the performance of cooling the heat-generating bodies 22, 27 can be made larger than that in the first embodiment.

[0191] In this case, air-cooling of the vehicle interior becomes impossible. In case where it is desired to perform both the cooling of the heat-generating bodies and the air-cooling of the vehicle interior simultaneously, two flow control valves instead of the three-way valve 94 and two flow control valves instead of the three-way valve 91 may be arranged.

[0192] That is, the flow control valves may be arranged on a circulation path leading to the air-conditioning interior heat exchanger 32, on the connection path 93, on the connection path 90, on a circulation path from the air-conditioning interior heat exchanger 32 to the circulation pump 33 upstream of the connection path 90, respectively to control the flow rate of the air-conditioning heat medium that flows on the side of the air-conditioning interior heat exchanger 23 and the air-conditioning heat medium that flows on the side of the connection path 93. In consideration of the possibility that the performance of cooling will be insufficient, two flow control valves may be arranged instead of the three-way valve 26. That is, the flow control valves may be arranged on the bypass route 21a and on the circulation path leading to the side of the cooling interior heat exchanger 23 to control flow rates of the cooling heat medium that flows on the side of the cooling interior heat exchanger 23 and the cooling heat medium that flows through the bypass route 21a.

[0193] Note that according to the third embodiment, the reservoir tank 24 is arranged on the circulation path between the heat-generating body 22 and the four-way valve 95. However, it may be arranged on a circulation path different therefrom.

Fourth Embodiment

[0194] A fourth embodiment of the heat cycle system 1 installed in EV 1000 is explained referring to FIG. 8.

[0195] The fourth embodiment is a variation of the first embodiment and the system is of the construction that enables only cooling operation and cooling/dehumidifying operation.

That is, according to the first embodiment, the direction of the flow of the refrigerant is switched between air-cooling and air-heating with the four-way valve 13. In contrast, according to the present embodiment, the discharge side of the compressor 12 is connected to the side of the exterior heat exchanger 14 and the intake side of the compressor 12 is connected to the side of the cooling intermediate heat exchanger and the air-cooling heat exchanger 50 to make a non-switchable, fixed connection structure. Such a structure is suitable for simplifying the heat cycle system 1 to be applied to EV 1000 for areas where no air-heating is required.

[0196] Note that the structures similar to those according to the first embodiment are indicated with the same reference numerals as those used in the first embodiment and explanation thereof is omitted.

Fifth Embodiment

[0197] A fifth embodiment of the heat cycle system 1 for a mobile object installed in EV 1000 is explained referring to FIG. 9.

[0198] The fifth embodiment is an improved variation of the fourth embodiment, in which there is provided a heat exchange unit that includes an exterior heat exchanger 28 and an exterior fan 28a between the reservoir tank 24 in the cooling heat medium circulation channel 21 and the circulation pump 25. With this construction, if troubles occur in the refrigeration cycle system 10, the cooling heat medium can be cooled by the heat exchange unit to continue cooling of the heat-generating body 22 with the cooling heat medium cooled by the heat exchange unit. As a result, the driving of EV 1000 can be continued by the actuation of the heat-generation body 22.

[0199] Note that the structures similar to those according to the fourth embodiment are indicated with the same reference numerals as those used in the fourth embodiment and explanation thereof is omitted.

[0200] The construction according to the fifth embodiment can be applied to other embodiments.

Sixth Embodiment

[0201] A sixth embodiment of the heat cycle system 1 for a mobile object installed in EV 1000 is explained referring to FIG. 10.

[0202] The sixth embodiment is an improved variation of the first embodiment, in which the reservoir tank 24 is arranged at a position higher than the highest portions of the cooling heat medium circulation path 21 and the air-conditioning heat medium circulation path 31 and the reservoir tank 24 and the cooling heat medium circulation path 21 are connected through a connection path 61 while the reservoir tank 24 and the air-conditioning heat medium circulation path 31 are connected through a connection path 62. With this construction, the same function as that of the first embodiment can be achieved. Therefore, according to the sixth embodiment, effects similar to those according to the first embodiment can be obtained.

[0203] Note that the structures similar to those according to the first embodiment are indicated with the same reference numerals as those used in the first embodiment and explanation thereof is omitted.

[0204] The construction according to the sixth embodiment can be applied to other embodiments.

[0205] In the above, various embodiments and variations thereof are explained. However, the present invention should not be construed as being limited thereto. Other embodiments conceivable within the technical concept of the present invention are understood to be encompassed by the scope of the present invention.

[0206] The disclosure of the following priority application is incorporated by reference herein: Japanese Patent Application No. 2009-270979 (filed on Nov. 30, 2009).

1. A heat cycle system for a mobile object, comprising:
 - a refrigeration cycle system in which a refrigerant flows;
 - a first heat transfer system in which a heat medium that controls a temperature of a heat-generating body flows;
 - a second heat transfer system in which a heat medium that controls a state of air in an interior of the mobile object flows;
 - a first intermediate heat exchanger which is provided between the refrigeration cycle system and the first heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween;
 - a second intermediate heat exchanger which is provided between the refrigeration cycle system and the second heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween;
 - a first interior heat exchanger which is provided in the first heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween;
 - a second interior heat exchanger which is provided in the second heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and
 - a reservoir tank that controls pressures in flow channels in which the heat media in the first and second heat transfer systems, respectively, flow; wherein
- the reservoir tank is provided in common for the first and second heat transfer systems.
2. A heat cycle system for a mobile object according to claim 1, wherein
 - the reservoir tank is connected with a heat medium flow channel for the first heat transfer system and a heat medium flow channel for the second heat transfer system, respectively.
3. A heat cycle system for a mobile object according to claim 1, wherein
 - the reservoir tank is provided in either one of the heat medium flow channel for the first heat transfer system or the heat medium flow channel for the second heat transfer system, and
 - the heat medium flow channel for the first heat transfer system and the heat medium flow channel for the second heat transfer system communicate through a communication path.
4. A heat cycle system for a mobile object according to claim 1, further comprising:
 - a drainage mechanism that discharges the heat media from the heat medium flow channel for the first heat transfer system and the heat medium flow channel for the second heat transfer system, wherein
 - the drainage mechanism is provided in common between the first heat transfer system and the second heat transfer system.

5. A heat cycle system for a mobile object according to claim 1, further comprising:

- an exterior heat exchanger, provided in the first heat transfer system, that exchanges heat between the heat medium and exterior air.

6. A heat cycle system for a mobile object, comprising:

- a refrigeration cycle system in which a refrigerant flows;
- a first heat transfer system in which a heat medium that controls a temperature of a heat-generating body flows;
- a second heat transfer system in which a heat medium that controls a state of air in an interior of the mobile object flows;

- a first intermediate heat exchanger which is provided between the refrigeration cycle system and the first heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween;

- a second intermediate heat exchanger which is provided between the refrigeration cycle system and the second heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween;

- a first interior heat exchanger which is provided in the first heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween;

- a second interior heat exchanger which is provided in the second heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and

- a flow channel connection control unit that controls connection of a flow channel of the first heat transfer system and a flow channel of the second heat transfer system such that a heat medium fed to the heat-generating body is flown through the first and second intermediate heat exchangers in series.

7. A heat cycle system for a mobile object according to claim 6, wherein

- when a state is reached where an amount of heat exchange between the heat medium fed to the heat-generating body and the refrigerant is to be made larger than an amount of heat exchange between a heat medium fed to the heat-generating body and the refrigerant at the first intermediate heat exchanger, the flow channel connection control unit controls the connection between the flow channels such that a heat medium fed to the heat-generating body flows through the first and second intermediate heat exchangers in series.

8. A heat cycle system for a mobile object, comprising:

- a refrigeration cycle system in which a refrigerant flows;
- a first heat transfer system in which a heat medium that controls temperatures of at least two heat-generating bodies flows;

- a second heat transfer system in which a heat medium that controls a state of air in an interior of the mobile object flows;

- a first intermediate heat exchanger which is provided between the refrigeration cycle system and the first heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween;

- a second intermediate heat exchanger which is provided between the refrigeration cycle system and the second heat transfer system and in which the refrigerant and the heat medium exchange heat therebetween;

- a first interior heat exchanger which is provided in the first heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween;

- a second interior heat exchanger which is provided in the second heat transfer system and in which air taken into the interior of the mobile object and the heat medium exchange heat therebetween; and

- a flow channels switch unit that switches connections between the at least two heat-generating bodies and flow channels of the first and second heat transfer systems such that assuming the at least two heat-generating bodies are divided into two heat control object groups, the heat medium that flows in the first heat transfer system is circulated to one of the two heat control object groups and the heat medium that flows in the second heat transfer system is circulated to the other of the two heat control object groups.

9. A heat cycle system for a mobile object according to claim 8, wherein

- when a state is reached where an amount of heat exchange between the heat medium fed to the at least two heat-generating bodies and the at least two heat-generating bodies is to be made larger than an amount of heat exchange between the at least two heat-generating bodies and the heat medium of the first heat transfer system, the flow channels connection control unit controls the connections between the flow channels such that the heat medium that flows in the first heat transfer system is circulated to one of the temperature control object groups while the heat medium that flows in the second heat transfer system is circulated to the other of the temperature control object groups.

10. A heat cycle system for a mobile object according to claim 6, further comprising:

- a reservoir tank that controls respective pressures in flow channels in which the heat media of the first and second heat transfer systems flow, wherein

- the reservoir tank is provided in common to the first and second heat transfer systems.

11. A heat cycle system for a mobile object according to claim 6, further comprising:

- a drainage mechanism that discharges the heat medium from the heat medium flow channel for the first heat transfer system and the heat medium flow channel for the second heat transfer system, wherein

- the drainage mechanism is provided in common between the first heat transfer system and the second heat transfer system.

12. A heat cycle system for a mobile object according to claim 6, further comprising:

- an exterior heat exchanger, provided in the first heat transfer system, that exchanges heat between the heat medium and exterior air.

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