



US 20140298830A1

(19) **United States**

(12) **Patent Application Publication**  
**Won**

(10) **Pub. No.: US 2014/0298830 A1**

(43) **Pub. Date: Oct. 9, 2014**

(54) **AIR CONDITIONER FOR ELECTRIC  
VEHICLE**

(57) **ABSTRACT**

(71) Applicant: **V-EN CO., LTD.**, Incheon (KR)

(72) Inventor: **You Sung Won**, Incheon (KR)

(73) Assignee: **LG ELECTRONICS INC.**, Seoul (KR)

(21) Appl. No.: **14/355,377**

(22) PCT Filed: **Aug. 9, 2013**

(86) PCT No.: **PCT/KR2013/007193**

§ 371 (c)(1),  
(2), (4) Date: **Apr. 30, 2014**

(30) **Foreign Application Priority Data**

Aug. 10, 2012 (KR) ..... 10-2012-0087892

**Publication Classification**

(51) **Int. Cl.**  
**B60H 1/00** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **B60H 1/00428** (2013.01); **B60H 1/00007**  
(2013.01)

USPC ..... **62/79**; 62/238.6; 62/238.7; 62/324.6

An air conditioner of an electric vehicle according to the present invention includes a compressor for compressing refrigerant, an indoor heat exchanger for performing heat exchange between refrigerant introduced into the indoor heat exchanger after emerging from the compressor and air, an outdoor heat exchanger for performing heat exchange between refrigerant introduced into the outdoor heat exchanger and outdoor air, a first expansion device arranged between the indoor heat exchanger and the outdoor heat exchanger, to expand refrigerant introduced into the first expansion device, an evaporator for evaporating refrigerant introduced into the evaporator, to dehumidify indoor air, a second expansion device arranged between the outdoor heat exchanger and the evaporator, to expand refrigerant introduced into the second expansion device, a first bypass line connected to guide refrigerant emerging from the indoor heat exchanger to flow toward the evaporator after bypassing the first expansion device and the outdoor heat exchanger, and a second bypass line connected to guide refrigerant flowing toward the evaporator to flow toward the compressor after bypassing the evaporator. During a heating operation, the first bypass line is selectively used in accordance with an outdoor temperature, and the second bypass line is selectively used in accordance with an indoor humidity.

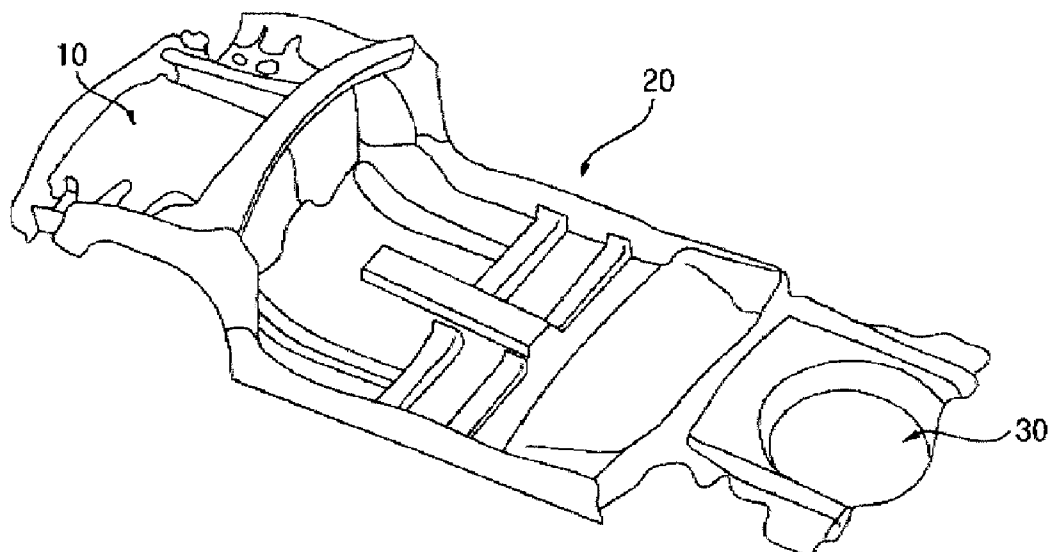


Fig. 1

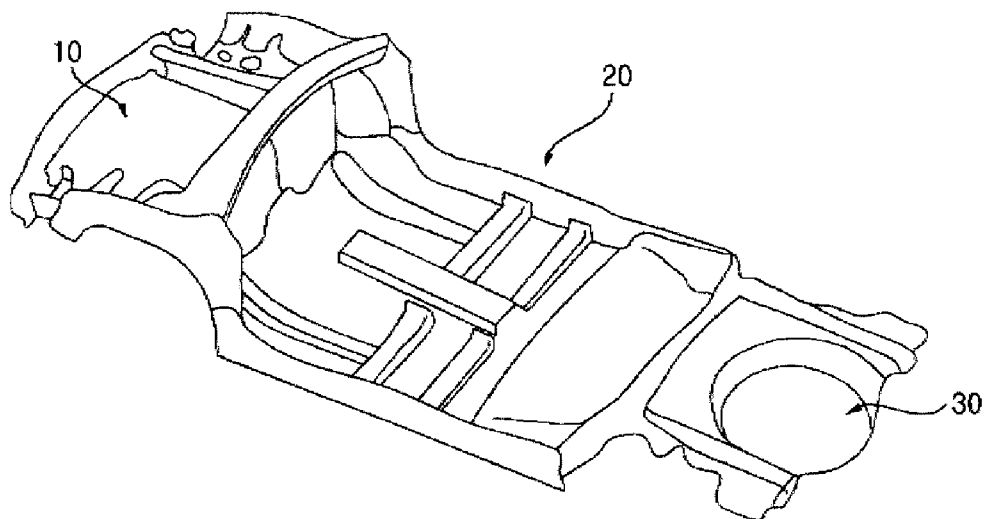


Fig. 2

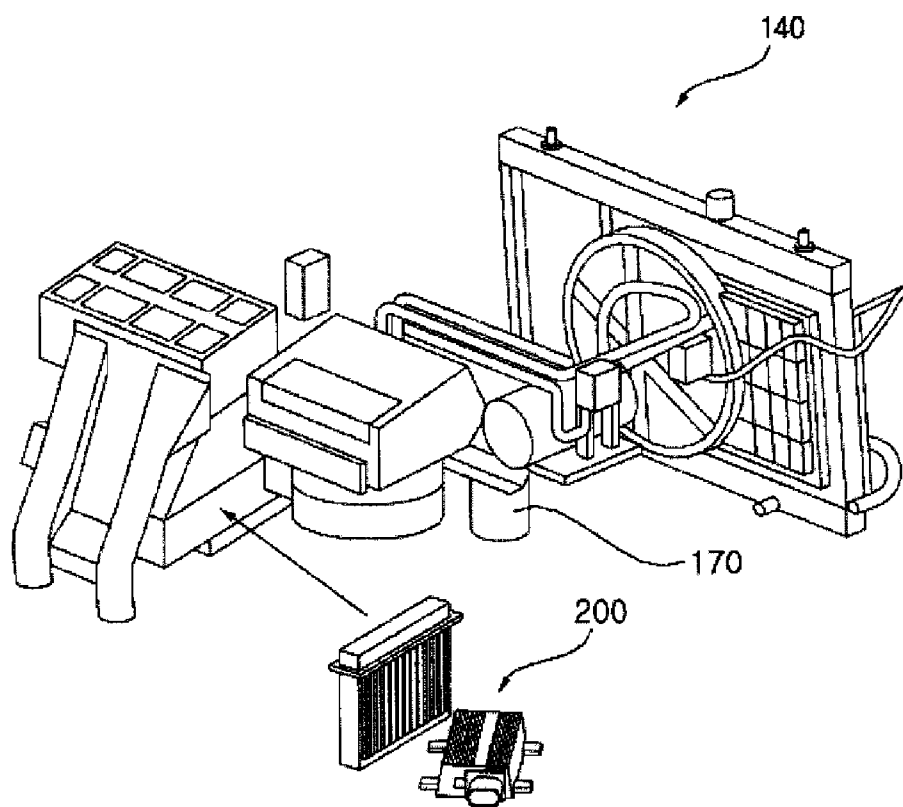
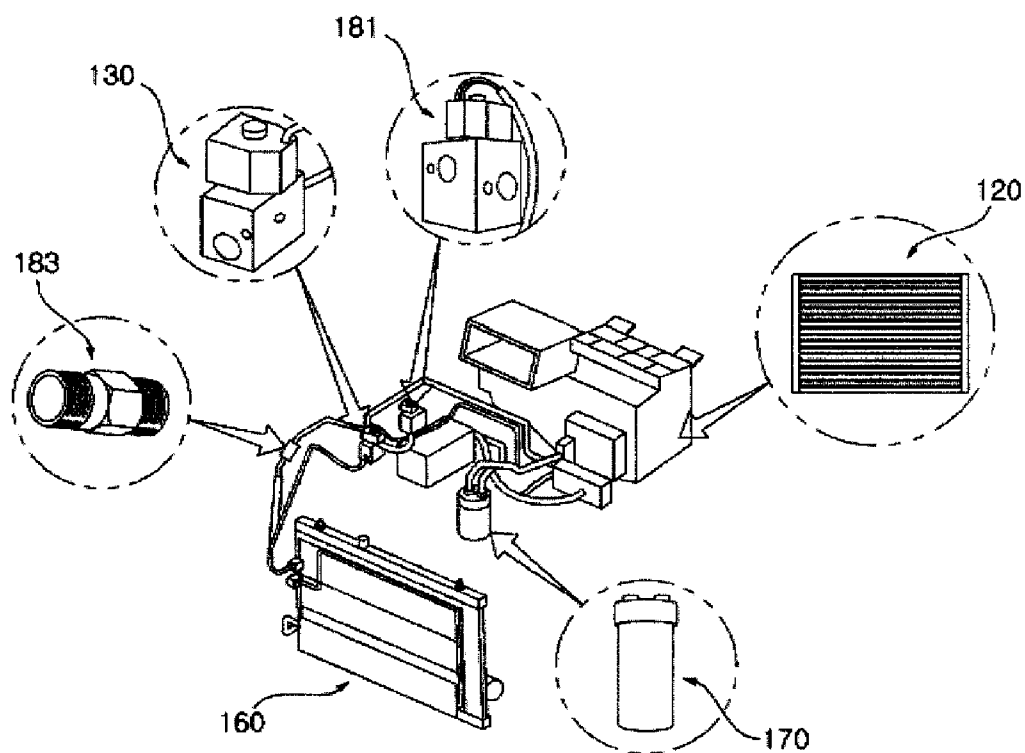


Fig. 3



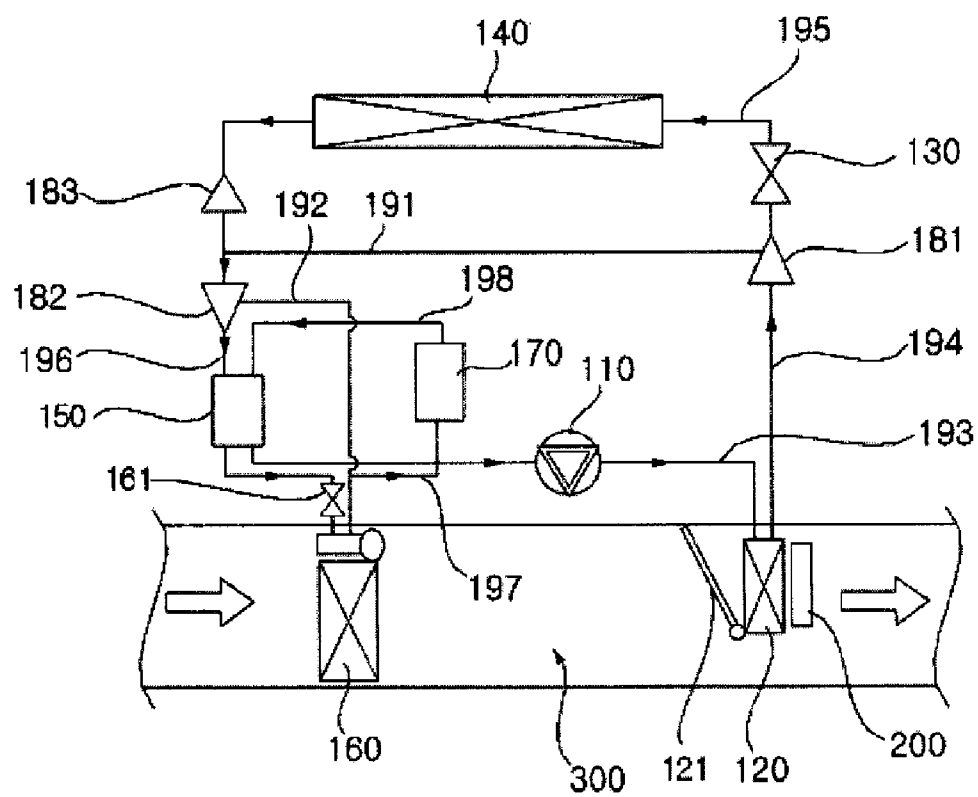


Fig. 5

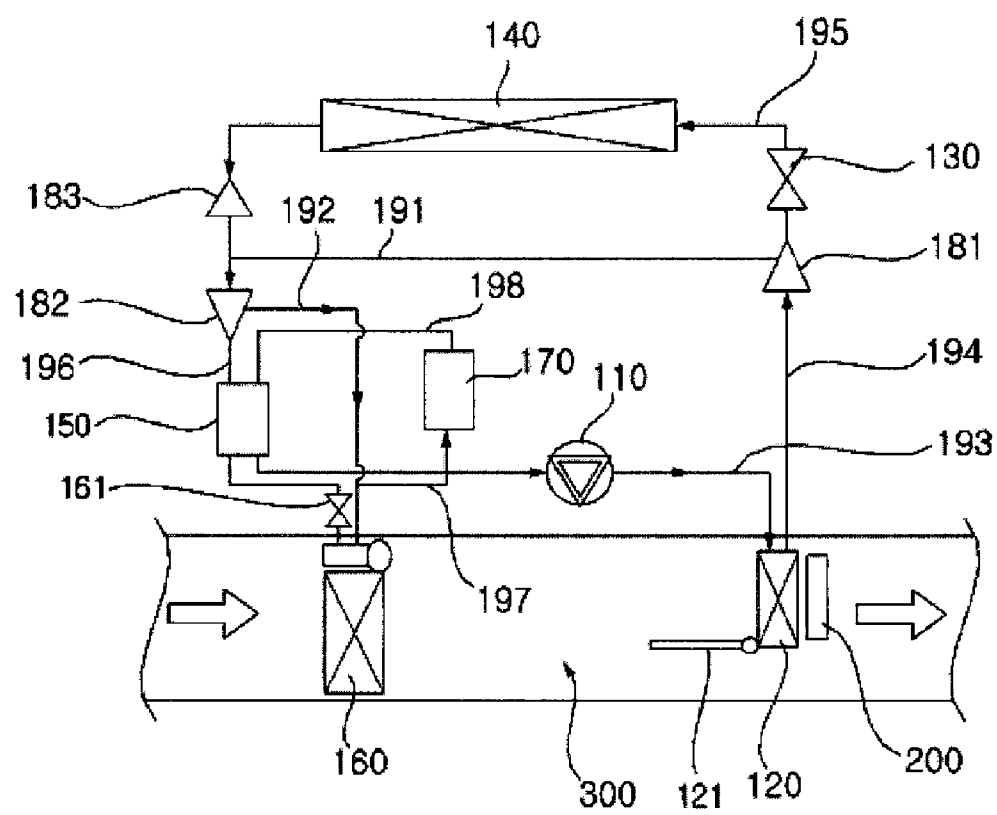


Fig. 6

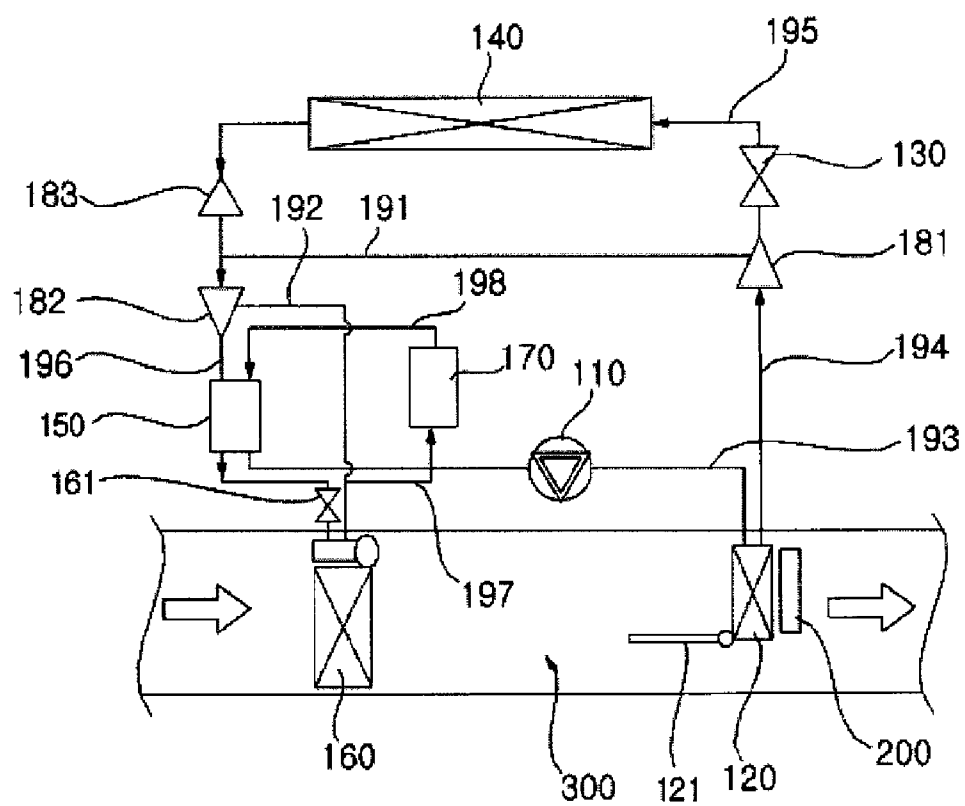
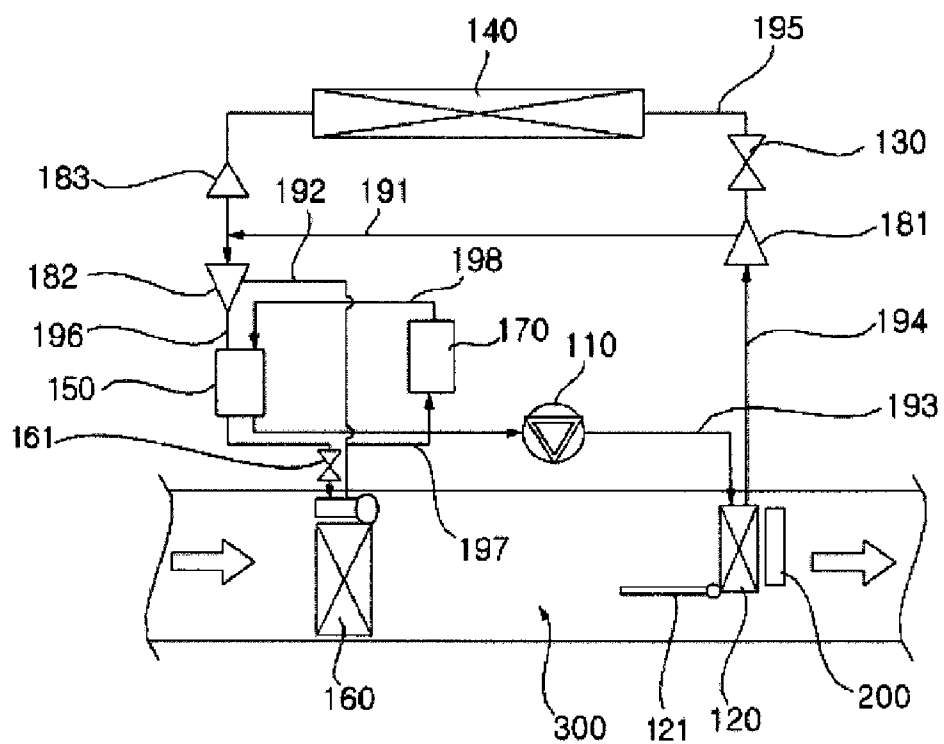


Fig. 7



## AIR CONDITIONER FOR ELECTRIC VEHICLE

### TECHNICAL FIELD

[0001] The present invention relates to an air conditioner for an electric vehicle, and more particularly to an air conditioner of an electric vehicle, to which an air conditioner exhibiting low power consumption is applied.

### BACKGROUND ART

[0002] Vehicle is a transportation means for transporting passengers or goods on roads through transmission of drive power generated from an engine of the transportation means to wheels of the transportation means. Such a vehicle may mainly include a body defining an appearance of the vehicle, and a chassis, to which various devices are organically connected. The chassis not only includes a vehicle engine functioning as motive power, but also includes essential devices such as a power transmission, a steering device, a suspension, and a braking device.

[0003] Engine is a motive to enable a vehicle to run. Most vehicle engines are 4-stroke internal combustion engines. Such a 4-stroke internal combustion engine is an internal combustion engine completing one cycle through suction, compression, explosion, and exhaustion, and is a most general example of a reciprocating engine. In an internal combustion engine, which mainly uses volatile fuel, the fuel is compressed in a state of being mixed well with atmospheric oxygen, for complete combustion, and is then burnt and, as such, kinetic energy is obtained through direct utilization of thermal energy generated during combustion of the fuel.

[0004] Such an internal engine, which uses volatile fuel, causes environmental pollution due to generation of exhaust gas, and exhausts petroleum resources. As a substitute, a vehicle using electricity as motive power thereof has been proposed.

[0005] An electric vehicle (EV) is a vehicle in which motive power is obtained through driving of an AC or DC motor mainly using electric power from a battery. EVs are classified into a battery vehicle and a hybrid vehicle. In the battery vehicle, a motor is driven, using electric power from a battery. When electric power of the battery is completely discharged, the battery is recharged. In the hybrid vehicle, electricity is generated through driving of an engine, to charge a battery. Using the charged electricity, an electric motor is driven, to move the vehicle.

[0006] Hybrid vehicles may be classified into a series type hybrid vehicle and a parallel type hybrid vehicle. In the series type hybrid vehicle, mechanical energy output from an engine is converted through a generator into electric energy which is, in turn, supplied to a battery or a motor. The vehicle of this type is a vehicle always driven by a motor. The concept of this vehicle is addition of an engine and a generator to an existing vehicle so as to increase range of the vehicle. In the parallel type hybrid vehicle, two power sources are used such that the vehicle is driven, not only through an engine (gasoline or diesel), but also using electric power from a battery. In the parallel type hybrid vehicle, both the engine and the motor may be simultaneously driven to drive the vehicle in accordance with traveling conditions.

[0007] In the EV driven by battery power, it is most important to minimize consumption of battery power. Meanwhile, such an EV employs an air conditioner including a heater

mounted in front of an evaporator of the vehicle, to direct heat air during heating, as in general internal combustion engine vehicles. However, such a system heating indoor air by a heater has a problem in that consumption of electric power is very high.

[0008] Furthermore, there is a problem in that range of the EV is reduced due to use of the air conditioner exhibiting high power consumption.

### DISCLOSURE

#### Technical Problem

[0009] It is an object of the present invention to provide an air conditioner of an electric vehicle which exhibits low power consumption.

[0010] The objects of the present invention are not limited to the above-described objects, and other objects not described herein will be more clearly understood by those skilled in the art from the following description.

#### Technical Solution

[0011] In accordance with an aspect of the present invention, the above and other objects can be accomplished by the provision of an air conditioner of an electric vehicle including a compressor for compressing refrigerant, an indoor heat exchanger for performing heat exchange between refrigerant introduced into the indoor exchanger after emerging from the compressor and air, an outdoor heat exchanger for performing heat exchange between refrigerant introduced into the outdoor heat exchanger and outdoor air, a first expansion device arranged between the indoor heat exchanger and the outdoor heat exchanger, to expand refrigerant introduced into the first expansion device, an evaporator for evaporating refrigerant introduced into the evaporator, to dehumidify indoor air, a second expansion device arranged between the outdoor heat exchanger and the evaporator, to expand refrigerant introduced into the second expansion device, a first bypass line connected to guide refrigerant emerging from the indoor heat exchanger to flow toward the evaporator after bypassing the first expansion device and the outdoor heat exchanger, and a second bypass line connected to guide refrigerant flowing toward the evaporator to flow toward the compressor after bypassing the evaporator, wherein, during a heating operation, the first bypass line is selectively used in accordance with an outdoor temperature, and the second bypass line is selectively used in accordance with an indoor humidity.

[0012] The air conditioner may further include a first switch valve for performing a switching operation to allow refrigerant flowing toward the first expansion device to flow toward the first bypass line in a low-temperature heating mode, and a second switch valve for performing a switching operation to allow refrigerant flowing toward the evaporator to flow toward the second bypass line in a non-dehumidification mode.

[0013] The air conditioner may further include an air introduction blocking member for preventing air having exchanged heat with the indoor heat exchanger from being introduced into a passenger compartment in a low-temperature dehumidification heating mode, and a check valve for preventing refrigerant flowing toward the first bypass line from flowing toward the outdoor heat exchanger.

[0014] In accordance with another aspect of the present invention, there is provided a method for controlling the air

conditioner of the electric vehicle including, in a dehumidification heating mode, switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the outdoor heat exchanger, switching the second switch valve to allow refrigerant emerging from the outdoor heat exchanger to flow toward the evaporator, and turning off the first expansion device while turning on the second expansion device.

**[0015]** The method may further include, in the dehumidification heating mode, opening the check valve while opening the air introduction blocking member, and turning off the heater.

**[0016]** The method may further include, in a non-dehumidification heating mode, switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the outdoor heat exchanger, switching the second switch valve to allow refrigerant emerging from the outdoor heat exchanger to flow toward the second bypass line, and turning on the first expansion device while turning off the second expansion device.

**[0017]** The method may further include, in the non-dehumidification heating mode, opening the check valve while opening the air introduction blocking member, and turning off the heater.

**[0018]** The method may further include, in a low-temperature heating mode, switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the second switch valve without passing through the outdoor heat exchanger, switching the second switch valve to allow refrigerant emerging from the first switch valve to flow toward the evaporator, and turning on the second expansion device.

**[0019]** The method may further include, in the low-temperature dehumidification heating mode, closing the check valve while opening the air introduction blocking member, and turning on the heater.

**[0020]** In another aspect of the present invention, there is provided a method for controlling the air conditioner of the electric vehicle including, in a dehumidification cooling mode, switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the outdoor heat exchanger, switching the second switch valve to allow refrigerant emerging from the second switch valve to flow toward the evaporator, opening the check valve while closing the air introduction blocking member, and turning off the first expansion device while turning on the second expansion device.

**[0021]** In another aspect of the present invention, there is provided an air conditioner of an electric vehicle including a compressor for compressing refrigerant, an indoor heat exchanger for performing heat exchange between refrigerant introduced into the indoor exchanger after emerging from the compressor and air, an outdoor heat exchanger for performing heat exchange between refrigerant introduced into the outdoor heat exchanger and outdoor air, a first expansion device arranged between the indoor heat exchanger and the outdoor heat exchanger, to expand refrigerant introduced into the first expansion device, an evaporator for evaporating refrigerant introduced into the evaporator, to dehumidify indoor air, a second expansion device arranged between the outdoor heat exchanger and the evaporator, to expand refrigerant introduced into the second expansion device, a first bypass line connected to guide refrigerant emerging from the indoor heat exchanger to flow toward the evaporator after bypassing the

first expansion device and the outdoor heat exchanger, and a second bypass line connected to guide refrigerant flowing toward the evaporator to flow toward the compressor after bypassing the evaporator, a first switch valve for performing a switching operation to allow refrigerant flowing toward the first expansion device to flow toward the first bypass line, and a second switch valve for performing a switching operation to allow refrigerant flowing toward the evaporator to flow toward the second bypass line, wherein the air conditioner has a low-temperature heating mode for allowing refrigerant flowing toward the first expansion device to flow toward the first bypass line, a dehumidification heating mode for using the indoor heat exchanger and the outdoor heat exchanger as condensers, respectively, a non-dehumidification heating mode for allowing refrigerant flowing toward the evaporator to flow toward the second bypass line, and a dehumidification heating mode for allowing refrigerant emerging from the outdoor heat exchanger to flow toward the evaporator, wherein the air conditioner operates in one of the dehumidification heating mode, the non-dehumidification heating mode, and the low-temperature heating mode.

**[0022]** Detailed matters of other embodiments are included in the detailed description and the drawings.

#### Advantageous Effects

**[0023]** In accordance with the air conditioner of the electric vehicle of the present invention, there are one or more effects as follows.

**[0024]** First, there is an advantage in that power consumption is low when air in the passenger compartment is cooled/heated.

**[0025]** Second, there is an advantage in that range of the electric vehicle is increased in accordance with low power consumption.

**[0026]** Third, there is an advantage in that defrosting operation is not required because, during heating operation, primary heating is carried out under the condition that refrigerant is controlled in pressure and temperature to avoid formation of frost on the evaporator, and shortage of heat is supplemented by the heater.

**[0027]** Fourth, there is an advantage in that the air conditioner can operate in various operation modes in accordance with an outdoor temperature or indoor humidity.

**[0028]** Effects of the present invention are not limited to the above-described effects. Other effects not described can be clearly understood by those skilled in the art from the description of the claims.

#### DESCRIPTION OF DRAWINGS

**[0029]** The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

**[0030]** FIG. 1 is a view schematically illustrating a body of an electric vehicle according to an embodiment of the present invention;

**[0031]** FIG. 2 is a perspective view schematically illustrating parts of an air conditioner of the electric vehicle according to the embodiment of the present invention;

**[0032]** FIG. 3 is an exploded perspective view schematically illustrating the air conditioner of the electric vehicle according to the embodiment of the present invention;

[0033] FIG. 4 is a view schematically illustrating a flow of refrigerant during dehumidification cooling operation of the air conditioner of the electric vehicle according to the embodiment of the present invention;

[0034] FIG. 5 is a view schematically illustrating a flow of refrigerant during non-dehumidification heating operation of the air conditioner of the electric vehicle according to the embodiment of the present invention;

[0035] FIG. 6 is a view schematically illustrating a flow of refrigerant during dehumidification heating operation of the air conditioner of the electric vehicle according to the embodiment of the present invention; and

[0036] FIG. 7 is a view schematically illustrating a flow of refrigerant during low-temperature heating operation of the air conditioner of the electric vehicle according to the embodiment of the present invention.

#### BEST MODE

[0037] Referring to embodiments of the present invention described hereinafter in detail with reference to the accompanying drawings, advantages and features of the present invention and methods for accomplishing the same will be clarified. The present invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like reference numerals refer to like elements throughout.

[0038] Hereinafter, the present invention will be described with reference to the drawings for explaining an air conditioner 100 of an electric vehicle according to embodiments of the present invention.

[0039] FIG. 1 is a view schematically illustrating a body of an electric vehicle according to an embodiment of the present invention.

[0040] Referring to FIG. 1, the vehicle according to the embodiment of the present invention includes a front body 10, a central body 20, and a rear body 30.

[0041] The body defines an enclosed space in which various devices are arranged, and passengers or goods are received. It may be necessary for the body to have a structure capable of opening or closing a portion of the enclosed space in order to allow access of passengers or goods to the space, and easy maintenance and repair of the devices. In addition, the body has an important function to protect passengers, goods and the devices from external rain, wind, dust, etc. The body is an exterior and, as such, the shape of the body defines the shape of the vehicle.

[0042] The front body 10, on which elements of a power source and a power transmission system are mounted, forms a “#” shape and is provided with the power source and a transmission. Installed at the front body 10 are a steering device for adjusting a rotation axis direction of front wheels in order to change an advance direction of the vehicle 1, a front wheel suspension for preventing vibrations from a road from being directly transferred to the body, and an air conditioner for cooling, heating and dehumidifying a passenger compartment of the vehicle.

[0043] In addition to mounting of heavy elements such as the power source, transmission, and various auxiliary mechanisms, the front body 10 should support the front wheels of the front wheel suspension. When the vehicle is front-wheel drive, the front body 10 also bears driving force.

[0044] Upon receiving strong impact due to an accident, the front body 10 is damaged by absorbing the impact and, as such, strong force is not transferred to the passenger compartment. The elements installed at the front body 10 are fastened to the front body 10 by bolts and nuts or are welded to the front body 10. Only the exterior elements such as front fenders and a hood are separable.

[0045] The central body 20, in which passengers sit, includes a front floor panel to form a floor of a front passenger compartment, a tunnel provided at a central portion of the front floor panel, and side sill panels provided at opposite side edges of the front floor panel, to form floor side surfaces, respectively.

[0046] Since the central body 20 mainly forms the passenger compartment of the vehicle, namely, forms a space, in which passengers sit, the inner space of the central body 20 is designed to be as large as possible. Doors are mounted to lateral sides of the central body 20 in order to prevent external rain, wind, etc. from entering the inner space of the central body 20. The front floor panel forms a floor of the passenger compartment and, as such, is a panel having high strength and a large area. The side sill panels, which form pillar bases, are connected to left and right sides of the front floor panel throughout the length of the front floor panel, respectively. The tunnel is arranged at the central portion of the front floor.

[0047] The rear body 30, on which a spare tire and other articles are stored, includes a rear floor panel to form a floor of the rear body 30. The rear body 30 is provided with a rear wheel suspension to prevent vibrations from a road from being directly transferred to the body. It is necessary for the rear body 30 to support rear wheels of the rear wheel suspension. When the vehicle is of a rear-wheel drive type, the rear body 30 also bears driving force. The rear body 30 is provided with a rear bumper to absorb impact upon rear collision.

[0048] FIG. 2 is a perspective view schematically illustrating parts of an air conditioner of the electric vehicle according to the embodiment of the present invention. FIG. 3 is an exploded perspective view schematically illustrating the air conditioner of the electric vehicle according to the embodiment of the present invention.

[0049] Referring to FIGS. 2 and 3, the air conditioner of the electric vehicle according to the embodiment of the present invention includes a compressor 110, an indoor heat exchanger 120, a first expansion device 130, an outdoor heat exchanger 140, an evaporator 160, a second expansion device 161, a first switch valve 181, a second switch valve 182, a check valve 183, a supercooler 150, an accumulator 170, and a heater 200. The above-described elements, except for the heater 200, are connected by lines, through which refrigerant flows.

[0050] The second expansion device 161 may be integrated with the evaporator 160.

[0051] Thus, the air conditioner of the electric vehicle includes a first connection line 193 to connect the compressor 110 and indoor heat exchanger 120, a second connection line 194 to connect the indoor heat exchanger 120 and first expansion device 130, a third connection line 195 to connect the first expansion device 130 and outdoor heat exchanger 140, a fourth connection line 196 to connect the outdoor heat exchanger 140 and evaporator 160, a fifth connection line 197 to connect the evaporator 160 and accumulator 170, and a sixth connection line 198 to connect the fifth connection line 197 and accumulator 170.

[0052] The compressor 110 compresses low-temperature and low-pressure refrigerant introduced thereinto into high-temperature and high-pressure refrigerant. Various structures may be applied to the compressor 110. The compressor 110 may be of an inverter type or a constant speed type. The compressor 110 may be connected to the accumulator 170 in order to prevent liquid refrigerant from entering the compressor 110. As the compressor 110, a multi-stage compressor may be used. An oil separator (not shown) may be installed at a discharge line of the compressor 110 in order to collect oil contained in refrigerant discharged from the compressor 110.

[0053] The indoor heat exchanger 120 condenses high-temperature and high-pressure refrigerant introduced thereinto into low-temperature and low-pressure refrigerant. Upon condensing refrigerant, the indoor heat exchanger 120 discharges the heat.

[0054] The indoor heat exchanger 120 is arranged at an air line 300, through which indoor air flows. In detail, the inner heat exchanger 120 is arranged at an indoor air discharge side of the air line 300. Accordingly, the inner heat exchanger 120 discharges heat to indoor air during heating operation thereof and, as such, heats indoor air.

[0055] The air conditioner 100 of the electric vehicle may further include an air introduction blocking member 121 arranged at the air line 300, to prevent air having exchanged heat with the indoor heat exchanger 120 from being introduced into the passenger compartment. The air introduction blocking member 121 prevents heat of the indoor heat exchanger 120 from being introduced into the passenger compartment of the vehicle during cooling operation of the air conditioner 100 of the electric vehicle. A damper is an example of the air introduction blocking member 121. Of course, the present invention is not limited to the above-described example.

[0056] The compressor 110 and indoor heat exchanger 120 are connected by the first connection line, through which refrigerant flows. High-temperature and high-pressure refrigerant discharged from the compressor 110 flows through the first connection line 193 and, as such, the first connection line 193 is preferably made of a material exhibiting excellent heat resistance and corrosion resistance.

[0057] The first expansion device 130 is arranged between the indoor heat exchanger 120 and the outdoor heat exchanger 140, to expand refrigerant introduced thereinto. Accordingly, the first expansion device 130 throttles refrigerant emerging from the indoor heat exchanger 120. The first expansion device 130 may be constituted by an electronic expansion valve or an orifice valve. The orifice valve is a constant pressure expansion valve used to reduce pressure of refrigerant through a throttling function.

[0058] The first expansion device 130 and indoor heat exchanger 120 are connected by the second connection line 194. The first switch valve 181 is arranged at the second connection line 194. A first bypass line 191 is connected to guide refrigerant emerging from the indoor heat exchanger 120 to flow toward the evaporator 160 after bypassing the first expansion device 130 and outdoor heat exchanger 140. The first bypass line 191 is connected to the second connection line 194 via the first switch valve 181. That is, the first bypass line 191 is connected to the first switch valve 181.

[0059] The first switch valve 181 connects the indoor heat exchanger 120, first expansion device 130, and first bypass line 191. Thus, the first switch valve 181 carries out a switching operation to allow refrigerant flowing toward the first

expansion device 130 to flow through the first bypass line 191 in a low-temperature heating mode.

[0060] A switch valve is a direction change valve for switching a flow direction of a fluid. Generally, such a switch valve includes a two-way valve, a three-way valve, a four-way valve, etc. In the present invention, the first switch valve 191 is preferably constituted by a three-way valve so as to connect the indoor heat exchanger 120, first expansion device 130, and first bypass line 191.

[0061] The outdoor heat exchanger 140 performs heat exchange between refrigerant introduced into the outdoor heat exchanger 140 and outdoor air. Accordingly, the outdoor heat exchanger 140 functions as a condenser during cooling operation, and functions as an evaporator during heating operation. The outdoor heat exchanger 140 is connected with the first expansion device 130 via the third connection line 195. The outdoor heat exchanger 140 is also connected to the evaporator 160 via the fourth connection line 196.

[0062] The fourth connection line 196 is connected to the first bypass line 191. The check valve is arranged at the fourth connection line 196. The check valve prevents refrigerant flowing through the first bypass line 191 from flowing toward the outdoor heat exchanger 140 during a low-temperature heating mode. The second switch valve 182 and evaporator 160 are arranged at the fourth connection line 196.

[0063] The second bypass line 192 is connected to guide refrigerant flowing toward the evaporator 192 to flow toward the compressor 110 after bypassing the evaporator 160. Thus, the second bypass line 192 is a line, through which refrigerant flows during non-dehumidification operation. The second bypass line 192 is connected to the fourth connection line 196 via the second switch valve 182. That is, the second bypass line 192 is connected to the second switch valve 182.

[0064] The second switch valve connects the supercooler 150, fourth connection line 196, and second bypass line. Accordingly, the second switch valve performs a switching operation to allow refrigerant flowing toward the evaporator 160 to flow through the second bypass line 192. The second switch valve 182 is preferably constituted by a three-way valve because it connects the supercooler 150, fourth connection line 196, and second bypass line 192.

[0065] The supercooler 150 performs heat exchange between refrigerant flowing between the evaporator 160 and the outdoor heat exchanger 140 and refrigerant flowing between the accumulator 170 and the compressor 110. That is, the supercooler 150 performs heat exchange between refrigerant flowing through the fourth connection line 196 and refrigerant flowing through a sixth connection line 198, which will be described later.

[0066] A heat exchanger such as the above-described outdoor heat exchanger 140 or supercooler 150 is a device for transferring heat from a high-temperature medium to a low-temperature medium. Generally, such a heat exchanger is used in a heater, a cooler, an evaporator, a condenser, etc. A heat transfer medium used to transfer heat to a target fluid is referred to as a "heat medium". On the other hand, a medium used to absorb heat from a target fluid is referred to as "refrigerant". In the present embodiment, R-134a or 1234yf is preferably used as a refrigerant.

[0067] The evaporator 160 evaporates refrigerant, to dehumidify and cool indoor air. The evaporator 160 is arranged at the air line 300, as will be described later. In detail, the evaporator 160 is arranged at an indoor air introduction side of the air line 300. Accordingly, the evaporator 160 absorbs

heat from air flowing through the air line **300**, to condense moisture contained in the air. That is, the evaporator **160** means a device for absorbing heat from the surroundings when a liquid is changed into gas through evaporation, and rapidly lowering the temperature of the surroundings.

[0068] The second expansion device **161** is arranged between the outdoor heat exchanger **140** and the evaporator **160**, to expand refrigerant introduced into the second expansion device **161**. Accordingly, the second expansion device **161** throttles refrigerant emerging from the outdoor heat exchanger **140**. The second expansion device **161** may be constituted by an electronic expansion valve or an orifice valve. The orifice valve is a constant pressure expansion valve used to reduce pressure of refrigerant through a throttling function.

[0069] The accumulator **170** is connected to the compressor **110**, and receives refrigerant. The accumulator **170** receives refrigerant discharged from the compressor **110** during indoor cooling operation. During heating operation, the accumulator **170** receives refrigerant emerging from the evaporator **160** or refrigerant introduced thereto via the second bypass line **192**.

[0070] The accumulator **170** is a device for performing a moisture separation function in order to supply only the gas-phase refrigerant to the compressor **110**. Preferably, the accumulator **170** is arranged at a suction side of the compressor **110**.

[0071] The heater **200** is arranged at the air line **300** in the vicinity of the indoor heat exchanger **120**. The heater **200** is connected to the indoor heat exchanger **120**, to discharge heat into indoor air. Accordingly, the heater **200** functions to heat indoor air, as an assistant of the indoor heat exchanger **120**, when the temperature of the indoor air is very low.

[0072] Preferably, the heater **200** is a PTC heater. PCT is barium titanate-based ceramic, and is a semiconductor exhibiting a rapid increase in electric resistance in response to an increase in temperature. Such PCT is a safe heating element substituting for nicrome wires. Such an element is used in an air conditioner, a hair drier, a clothes drying machine, etc. because it exhibits variation in resistance in accordance with variation in temperature and, as such, functions as a switch.

[0073] The air line **300** is a line, through which indoor air flows. The evaporator **160**, indoor heat exchanger **120**, and heater **200** are arranged at the air line **300**. The evaporator **160** may be arranged at the indoor air introduction side of the air line **300**, whereas the indoor heat exchanger **120** and heater **200** may be arranged at the indoor air discharge side of the air line **300**. Thus, indoor air may be cooled or heated after being dehumidified.

[0074] In the air conditioner **100** of the electric vehicle according to the embodiment of the present invention, each of the first expansion device **130**, first switch valve **181** and second switch valve **182** is preferably constituted by an electrically controllable valve. Accordingly, the first expansion device **130**, first switch valve **181** and second switch valve **182** operate, as described in the following Table 1. In this case, the first expansion device **130** may be implemented by an electronic expansion valve.

TABLE 1

Classification	First Switch Valve	First Expansion Device	Second Switch Valve
Dehumidification Cooling Operation	OFF	OFF	OFF
Non-dehumidification Heating Operation	OFF	ON	ON
Dehumidification Heating Operation	OFF	OFF	OFF
Low-temperature Heating Operation	ON	OFF	OFF

[0075] Of course, in another embodiment of the present invention, the air conditioner **100** of the electric vehicle may be constituted by excluding the supercooler **150** and accumulator **170** from the configuration of the air conditioner **100** of the electric vehicle according to the above-described former embodiment of the present invention. Accordingly, in the latter embodiment of the present invention may exclude the fifth connection line **197** and sixth connection line **198** from the air conditioner **100** of the electric vehicle according to the former embodiment of the present invention, and may include a seventh connection line, to which the evaporator **160** and compressor **110** are connected.

[0076] Hereinafter, functions of the air conditioner of the electric vehicle according to the present invention constituted as described above will be described.

[0077] FIG. 4 is a view schematically illustrating a flow of refrigerant during dehumidification cooling operation of the air conditioner of the electric vehicle according to the embodiment of the present invention. FIG. 5 is a view schematically illustrating a flow of refrigerant during non-dehumidification heating operation of the air conditioner of the electric vehicle according to the embodiment of the present invention. FIG. 6 is a view schematically illustrating a flow of refrigerant during dehumidification heating operation of the air conditioner of the electric vehicle according to the embodiment of the present invention. FIG. 7 is a view schematically illustrating a flow of refrigerant during low-temperature heating operation of the air conditioner of the electric vehicle according to the embodiment of the present invention.

[0078] Hereinafter, functions of the air conditioner of the electric vehicle according to the embodiment of the present invention will be described with reference to FIGS. 4 to 7.

[0079] Operation of the air conditioner of the electric vehicle according to the embodiment of the present invention is classified into cooling operation and heating operation. The cooling operation is also classified into dehumidification heating operation, non-dehumidification heating operation, and low-temperature heating operation.

[0080] Non-dehumidification operation may be defined by cooling operation or heating operation.

[0081] The air conditioner of the electric vehicle according to the embodiment of the present invention may operate in one of a dehumidification heating mode, non-dehumidification heating mode and a low-temperature heating mode. The air conditioner may operate in one of the above-described operation modes in accordance with an indoor temperature or indoor humidity.

[0082] For example, during heating operation, the first switch valve **181** may be switched to selectively use the first bypass line in accordance with an outdoor temperature, and

the second switch valve **182** may be switched to selectively use the second bypass line in accordance with indoor humidity.

[0083] The cycle of the air conditioner of the electric vehicle according to each operation is classified, as in the following Table 2.

TABLE 2

Classification	Refrigerant Flow				
	Compressor	Indoor Heat Exchanger	First Expansion Device	Outdoor Heat Exchanger	Evaporator
Dehumidification Cooling Operation	Comp.	Cond.	Pass	Cond.	Evap.
Indoor Non-dehumidification Heating Operation	Comp.	Cond.	Exp.	Exp.	—
Indoor Dehumidification Heating Operation	Comp.	Cond.	Pass	Cond.	Evap.
Indoor Low-temperature Heating Operation	Comp.	Cond.	—	—	Evap.

Comp.: Compression,  
Cond.: Condensation,  
Exp.: Expansion,  
Evap.: Evaporation

[0084] First, dehumidification cooling operation will be described with reference to FIG. 4. During dehumidification cooling operation, the compressor **110** compresses refrigerant. Accordingly, the refrigerant is changed into a high-temperature and high-pressure state.

[0085] The compressed refrigerant flows toward the indoor heat exchanger **120** along the first connection line **193**. In this case, heat is discharged. In this case, the air introduction blocking member **121** is closed, to prevent air heated in the indoor heat exchanger **120** from being introduced into the passenger compartment. High-temperature and high-pressure refrigerant emerging from the indoor heat exchanger **120** flows through the first expansion device **130** via the first switch valve **181** along the second connection line **194**. In this case, the first expansion device **130** is in an OFF state and, as such, the refrigerant is introduced into the outdoor heat exchanger **140** after passing through the third connection line **195** without phase change thereof.

[0086] Here, the OFF state of the first expansion device **130** means that refrigerant passes through the first expansion device **130** without being expanded.

[0087] The refrigerant in the outdoor heat exchanger **140** discharges heat and, as such, is phase-changed into low-temperature and high-pressure liquid refrigerant. The liquid refrigerant flows through the second switch valve **182** after passing through the check valve **183**, and is then introduced into the supercooler **150** along the fourth connection line **196**. In this case, the temperature of the refrigerant is lowered, through heat exchange, below the temperature lowered by the outdoor heat exchanger. This is because the refrigerant exchanges heat with chill refrigerant emerging from the evaporator **160**.

[0088] The liquid-phase refrigerant is expanded in the second expansion device **161** after passing through the supercooler **150**, and is then supplied to the evaporator **160**. The refrigerant is subjected to phase change and, as such, the temperature of the refrigerant is lowered. The refrigerant exchanges heat with air in the air line **300**. The air flowing through the air line **300** is cooled, and is then discharged into the passenger compartment of the vehicle.

[0089] Gas-phase chill refrigerant emerging from the evaporator **160** flows through the accumulator **170** after passing through the fifth connection line **197**. In this case, liquid-phase refrigerant, which has not been phase-changed, is separated without passing through the accumulator **170**. The gas-phase chill refrigerant again passes through the supercooler **150** after passing through the sixth connection line **198**. In this case, the refrigerant exchanges heat with the low-temperature and high-pressure refrigerant emerging from the second switch valve **182** and, as such, is changed into a refrigerant state having a lowered temperature. The resultant refrigerant is supplied to the evaporator **160**, and is then changed into a gas state having increased density while absorbing heat through heat exchange.

[0090] The gas-phase refrigerant is introduced into the compressor **110** after passing through the supercooler **150**, and is then circulated in the above-described manner.

[0091] Non-dehumidification heating operation will be described with reference to FIG. 5. During non-dehumidification heating operation, the compressor **110** compresses refrigerant. Accordingly, the refrigerant is changed into a high-temperature and high-pressure state.

[0092] The compressed refrigerant flows toward the indoor heat exchanger **120**. The refrigerant introduced into the indoor heat exchanger **120** is condensed. In accordance with condensation of the refrigerant, heat of the refrigerant is discharged into indoor air. Accordingly, the temperature of the refrigerant is lowered, whereas the temperature of the indoor air is raised. Thus, heating effects are generated. In this case, the air introduction blocking member **121** is in an opened state.

[0093] The condensed refrigerant flows toward the first switch valve **181** via the second connection line **194**. The first switch valve **181** performs a switching operation to allow refrigerant emerging from the indoor heat exchanger **120** to flow through the first expansion device **130** and outdoor heat exchanger **140**.

[0094] The first expansion device **130** is turned on. In an ON state of the first expansion device **130**, refrigerant introduced into the first expansion device **130** is expanded and, as such, the temperature and pressure of the expanded refrigerant are lowered. The opening degree of the first expansion device **130** is adjustable.

[0095] Refrigerant emerging from the first expansion device **130** flows toward the outdoor heat exchanger **140** via the third connection line **195**. The refrigerant introduced into the outdoor heat exchanger **140** exchanges heat with outdoor air. The refrigerant in the outdoor heat exchanger **140** is evaporated and, as such, absorbs heat from outdoor air. Accordingly, the temperature of the refrigerant is raised.

[0096] Refrigerant emerging from the outdoor heat exchanger **140** is changed in flow direction by the second switch valve **182**, to be bypassed toward the accumulator **170** via the second bypass line **192**. As a result, indoor air is not dehumidified. From the refrigerant introduced into the accu-

mulator 170, liquid-phase refrigerant is separated and, as such, only gas-phase refrigerant flows toward the compressor 110.

[0097] Dehumidification heating operation will be described with reference to FIG. 6. Dehumidification heating operation is similar to non-dehumidification heating operation and, as such, will be described mainly in conjunction with differences thereof from the non-dehumidification heating operation.

[0098] The compressor 110 compresses refrigerant. Accordingly, the refrigerant is changed into a high-temperature and high-pressure state.

[0099] The compressed refrigerant flows toward the indoor heat exchanger 120. The refrigerant introduced into the indoor heat exchanger 120 is primarily condensed. In accordance with condensation of the refrigerant, heat of the refrigerant is discharged into indoor air. Accordingly, the temperature of the refrigerant is lowered, whereas the temperature of the indoor air is raised. Thus, heating effects are generated. In this case, the air introduction blocking member 121 is in an opened state.

[0100] The refrigerant flows toward the first switch valve 181 via the second connection line 194. The first switch valve 181 performs a switching operation to allow refrigerant emerging from the indoor heat exchanger 120 to flow through the first expansion device 130 and outdoor heat exchanger 140.

[0101] The first expansion device 130 is turned off. Accordingly, refrigerant introduced into the first expansion device 130 passes through the first expansion device 130 without being expanded.

[0102] Refrigerant emerging from the first expansion device 130 flows toward the outdoor heat exchanger 140 via the third connection line 195. The refrigerant introduced into the outdoor heat exchanger 140 exchanges heat with outdoor air. The refrigerant in the outdoor heat exchanger 140 is secondarily condensed and, as such, discharges heat into outdoor air. Accordingly, the temperature of the refrigerant is lowered.

[0103] Refrigerant emerging from the outdoor heat exchanger 140 is introduced into the second switch valve 182. The second switch valve 182 is switched to allow refrigerant introduced therein to flow toward the evaporator 160.

[0104] Refrigerant emerging from the second switch valve 182 flows toward the evaporator 160 via the fourth connection line 196. The refrigerant flowing toward the evaporator 160 exchanges heat with refrigerant flowing along the sixth connection line 198, through the supercooler 150 arranged at the fourth connection line 196.

[0105] The second expansion device is turned on. Accordingly, the refrigerant flowing toward the evaporator 160 is introduced into the evaporator 160 after being expanded in the second expansion device 161. As a result, the refrigerant flowing toward the evaporator 160 is lowered in pressure and temperature.

[0106] The refrigerant introduced into the evaporator 160 is evaporated and, as such, absorbs heat from indoor air. Accordingly, indoor air may be humidified. Since the refrigerant absorbs heat from indoor air, the temperature of the refrigerant is raised. Refrigerant emerging from the evaporator 160 flows toward the accumulator 170. Refrigerant introduced into the accumulator 170 flows toward the compressor 110.

[0107] Low-temperature dehumidification heating operation will be described with reference to FIG. 7.

[0108] The compressor 110 compresses refrigerant. Accordingly, the refrigerant is changed into a high-temperature and high-pressure state.

[0109] The compressed refrigerant flows toward the indoor heat exchanger 120. The refrigerant introduced into the indoor heat exchanger 120 is condensed. In accordance with condensation of the refrigerant, heat of the refrigerant is discharged into indoor air. Accordingly, the temperature of the refrigerant is lowered, whereas the temperature of the indoor air is raised. Thus, heating effects are generated. In this case, the air introduction blocking member 121 is in an opened state.

[0110] In addition, the heat 200 may operate to supplement shortage of heat.

[0111] Refrigerant emerging from the indoor heat exchanger 120 is changed in flow direction by the first switch valve 181, to be bypassed toward the second switch valve 182 via the first bypass line 191.

[0112] The second switch valve 182 is switched to allow refrigerant emerging from the second switch valve 182 to flow toward the evaporator 160.

[0113] Refrigerant flowing toward the evaporator 160 by the first bypass line 191 flows toward the evaporator 160 via the fourth connection line 196. The refrigerant flowing toward the evaporator 160 exchanges heat with refrigerant flowing along the sixth connection line 198, through the supercooler 150 arranged at the fourth connection line 196. Accordingly, the refrigerant flowing toward the evaporator 160 is lowered in temperature while discharging heat.

[0114] Refrigerant emerging from the supercooler 150 is expanded in the second expansion device 161, and is then supplied to the evaporator 160. Refrigerant introduced into the evaporator 160 is evaporated and, as such, absorbs heat from indoor air. Thus, indoor air may be dehumidified. In addition, the temperature of the refrigerant is raised in accordance with absorption of heat from indoor air.

[0115] Refrigerant emerging from the evaporator 160 flows toward the accumulator 170. Refrigerant introduced into the accumulator 170 flows toward the compressor 110.

[0116] In accordance with an embodiment, when defrosting conditions are generated in the dehumidification heating mode, the dehumidification heating mode may be switched to the low-temperature dehumidification heating mode.

[0117] That is, when the evaporator 160 is at a very low temperature, frost or the like may be formed on the evaporator 160 and, as such, the air conditioner exhibits degraded efficiency. In this case, when the temperature of refrigerant in the evaporator 160 is raised through adjustment of the pressure of the refrigerant, the evaporator 160 is defrosted because degree of heat exchange in the indoor heat exchanger 120 is reduced. Shortage of heat is supplemented by the heater 200. Thus, there is an advantage in that separate defrosting operation is not required because the evaporator 160 operates at a raised temperature.

[0118] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

1. An air conditioner of an electric vehicle comprising:
  - a compressor for compressing refrigerant;
  - an indoor heat exchanger for performing heat exchange between refrigerant introduced into the indoor exchanger after emerging from the compressor and air;

- an outdoor heat exchanger for performing heat exchange between refrigerant introduced into the outdoor heat exchanger and outdoor air;
- a first expansion device arranged between the indoor heat exchanger and the outdoor heat exchanger, to expand refrigerant introduced into the first expansion device;
- an evaporator for evaporating refrigerant introduced into the evaporator, to dehumidify indoor air;
- a second expansion device arranged between the outdoor heat exchanger and the evaporator, to expand refrigerant introduced into the second expansion device;
- a first bypass line connected to guide refrigerant emerging from the indoor heat exchanger to flow toward the evaporator after bypassing the first expansion device and the outdoor heat exchanger, and
- a second bypass line connected to guide refrigerant flowing toward the evaporator to flow toward the compressor after bypassing the evaporator,
- wherein, during a heating operation, the first bypass line is selectively used in accordance with an outdoor temperature, and the second bypass line is selectively used in accordance with an indoor humidity.
- 2.** The air conditioner according to claim 1, further comprising:
- an accumulator connected to the compressor, the accumulator receiving refrigerant; and
  - a supercooler for performing heat exchange between refrigerant flowing between the evaporator and the outdoor heat exchanger and refrigerant flowing between the accumulator and the compressor.
- 3.** The air conditioner according to claim 2, further comprising:
- a first switch valve for performing a switching operation to allow refrigerant flowing toward the first expansion device to flow toward the first bypass line in a low-temperature heating mode; and
  - a second switch valve for performing a switching operation to allow refrigerant flowing toward the evaporator to flow toward the second bypass line in a non-dehumidification mode.
- 4.** The air conditioner according to claim 3, further comprising:
- a check valve for preventing refrigerant flowing toward the first bypass line from flowing toward the second switch valve and from flowing toward the outdoor heat exchanger.
- 5.** The air conditioner according to claim 4, further comprising:
- an air introduction blocking member for preventing air having exchanged heat with the indoor heat exchanger from being introduced into a passenger compartment in the low-temperature dehumidification heating mode.
- 6.** The air conditioner according to claim 5, further comprising:
- an air line, through which indoor air flows,
  - wherein the evaporator and the indoor heat exchanger are arranged at the air line,
  - wherein the evaporator is arranged at an air introduction side of the air line,
  - wherein the indoor heat exchanger is arranged at an air discharge side of the air line.
- 7.** A method for controlling the air conditioner of the electric vehicle according to claim 6, comprising:
- in a dehumidification heating mode,
  - switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the outdoor heat exchanger;
  - switching the second switch valve to allow refrigerant emerging from the outdoor heat exchanger to flow toward the evaporator; and
  - turning off the first expansion device while turning on the second expansion device.
- 8.** The method according to claim 7, further comprising:
- in the dehumidification heating mode,
  - opening the check valve while opening the air introduction blocking member; and
  - turning off the heater.
- 9.** The method according to claim 6, further comprising:
- in a non-dehumidification heating mode,
  - switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the outdoor heat exchanger;
  - switching the second switch valve to allow refrigerant emerging from the outdoor heat exchanger to flow toward the second bypass line; and
  - turning on the first expansion device while turning off the second expansion device.
- 10.** The method according to claim 9, further comprising:
- in the non-dehumidification heating mode,
  - opening the check valve while opening the air introduction blocking member; and
  - turning off the heater.
- 11.** The method according to claim 6, further comprising:
- in a low-temperature heating mode,
  - switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the second switch valve without passing through the outdoor heat exchanger;
  - switching the second switch valve to allow refrigerant emerging from the first switch valve to flow toward the evaporator; and
  - turning on the second expansion device.
- 12.** The method according to claim 11, further comprising:
- in the low-temperature dehumidification heating mode,
  - closing the check valve while opening the air introduction blocking member; and
  - turning on the heater.
- 13.** A method for controlling the air conditioner of the electric vehicle according to claim 6, comprising:
- in a dehumidification cooling mode,
  - switching the first switch valve to allow refrigerant emerging from the indoor heat exchanger to flow toward the outdoor heat exchanger;
  - switching the second switch valve to allow refrigerant emerging from the second switch valve to flow toward the evaporator;
  - opening the check valve while closing the air introduction blocking member; and
  - turning off the first expansion device while turning on the second expansion device.
- 14.** An air conditioner of an electric vehicle comprising:
- a compressor for compressing refrigerant;
  - an indoor heat exchanger for performing heat exchange between refrigerant introduced into the indoor heat exchanger after emerging from the compressor and air;

an outdoor heat exchanger for performing heat exchange between refrigerant introduced into the outdoor heat exchanger and outdoor air;

a first expansion device arranged between the indoor heat exchanger and the outdoor heat exchanger, to expand refrigerant introduced into the first expansion device;

an evaporator for evaporating refrigerant introduced into the evaporator, to dehumidify indoor air;

a second expansion device arranged between the outdoor heat exchanger and the evaporator, to expand refrigerant introduced into the second expansion device;

a first bypass line connected to guide refrigerant emerging from the indoor heat exchanger to flow toward the evaporator after bypassing the first expansion device and the outdoor heat exchanger, and

a second bypass line connected to guide refrigerant flowing toward the evaporator to flow toward the compressor after bypassing the evaporator,

a first switch valve for performing a switching operation to allow refrigerant flowing toward the first expansion device to flow toward the first bypass line; and

a second switch valve for performing a switching operation to allow refrigerant flowing toward the evaporator to flow toward the second bypass line,

wherein the air conditioner has a low-temperature heating mode for allowing refrigerant flowing toward the first expansion device to flow toward the first bypass line, a dehumidification heating mode for using the indoor heat exchanger and the outdoor heat exchanger as condensers, respectively, a non-dehumidification heating mode for allowing refrigerant flowing toward the evaporator to flow toward the second bypass line, and a dehumidification heating mode for allowing refrigerant emerging from the outdoor heat exchanger to flow toward the evaporator,

wherein the air conditioner operates in one of the dehumidification heating mode, the non-humidification heating mode, and the low-temperature heating mode.

**15.** The air conditioner according to claim **14**, wherein the air conditioner operates in one of the operation modes in accordance with an outdoor temperature or an indoor humidity.

**16.** The air conditioner according to claim **15**, wherein, when defrosting conditions are generated in the dehumidification heating mode, the dehumidification heating mode is switched to the low-temperature dehumidification heating mode.

\* \* \* \* \*